Document généré le 4 mai 2023 19:51

Géographie physique et Quaternaire

Laurentide Ice-Flow Patterns: A Historical Review, and Implications of the Dispersal of Belcher Islands Erratics

Historique des modes d'écoulement de l'Inlandsis laurentidien et incidences de la dispersion des blocs erratiques de l'archipel de Belcher

Victor K. Prest

Volume 44, numéro 2, 1990

URI : https://id.erudit.org/iderudit/032812ar
DOI : https://doi.org/10.7202/032812ar

Aller au sommaire du numéro

Éditeur(s)

Les Presses de l'Université de Montréal

ISSN

0705-7199 (imprimé)
1492-143X (numérique)

Découvrir la revue

Citer cet article

Prest, V. K. (1990). Laurentide Ice-Flow Patterns: A Historical Review, and Implications of the Dispersal of Belcher Islands Erratics. *Géographie physique et Quaternaire*, *44*(2), 113–136. https://doi.org/10.7202/032812ar

Résumé de l'article

On traite ici de l'évolution de la pensée en ce qui a trait à la configuration des grands mouvements glaciaires continentaux à l'est de la Cordillère. Les interprétations quant à l'étendue de l'Inlandsis laurentidien ont peu changé depuis un siècle (sauf pour l'Arctique), mais les questions sur la croissance, les centres de dispersion et l'écoulement glaciaire demeurent quelque peu controversées. Les données géologiques actuelles, toutefois, tendent à confirmer la notion de centres d'écoulement multiples. La première carte montrant l'étendue de la couverture glaciaire sur l'Amérique du Nord a été publiée en 1881. Le concept d'un inlandsis à dômes multiples a été illustré dans une carte de 1894 montrant l'écoulement radial à partir de zones de dispersion à l'est et à l'ouest de la baie d'Hudson. La première grande carte glaciaire de l'Amérique du Nord a été publiée en 1913. Le concept d'un inlandsis binaire a prévalu jusqu'en 1943, alors qu'on a mis de l'avant l'idée d'un seul centre dans la baie d'Hudson, en se fondant sur la croissance glaciaire vers l'ouest à partir du Québec-Labrador. Ce concept du dôme hudsonien a persisté, mais n'a pas été illustré avant 1977. Or, il apparaissait d'ores et déjà à partir des différentes études menées sur la dispersion des glaces que la thèse du dôme unique n'était pas juste. Les études sur la dispersion font état d'un écoulement glaciaire continu vers l'ouest, dans la partie sud de la baie d'Hudson et au delà, à partir du Québec, ainsi qu'un écoulement vers l'est dans la partie nord de la baie, à partir du Keewatin. La modélisation par ordinateur de l'Inlandsis laurentidien démontre bien la complexité des écoulements glaciaires. La répartition de blocs erratiques indicateurs du groupe de la zone de plissements d'âge protérozoïque de l'archipel de Belcher aide à préciser les modèles d'écoulement glaciaire. Ces errratiques ont largement été dispersés vers l'ouest, le sud-ouest et le sud à partir du secteur labradorien lors de plusieurs avancées de l'Inlandsis laurentidien. Ils sont abondants dans les terrains paléozoïques des basses terres des baies de James et d'Hudson, mais moins nombreux à travers les hautes terres archéennes adjacentes. Des blocs erratiques semblables sont courants dans le nord du Manitoba dans la zone de confluence des glaces du Labrador et du Keewatin. On trouve des blocs dispersés à travers les Prairies dans la zone d'écoulement des glaces du Keewatin vers le sud. En raison de leur absence probable au Keewatin, ont croit qu'il y aurait eu un changement de direction des glaces du Keewatin et dépôt seulement après une ou plusieurs avancées glaciaires antérieures en provenance du Labrador. La répartition des blocs erratiques indicateurs aide à éprouver les différents concepts sur la croissance de l'inlandsis.

Tous droits réservés © Les Presses de l'Université de Montréal, 1990

Ce document est protégé par la loi sur le droit d'auteur. L'utilisation des services d'Érudit (y compris la reproduction) est assujettie à sa politique d'utilisation que vous pouvez consulter en ligne.

https://apropos.erudit.org/fr/usagers/politique-dutilisation/

Cet article est diffusé et préservé par Érudit.

Érudit est un consortium interuniversitaire sans but lucratif composé de l'Université de Montréal, l'Université Laval et l'Université du Québec à Montréal. Il a pour mission la promotion et la valorisation de la recherche.

https://www.erudit.org/fr/

Géographie physique et Quaternaire, 1990, vol. 44, n° 2, p. 113-136, 29 fig., 1 tabl

LAURENTIDE ICE-FLOW PATTERNS: A HISTORICAL REVIEW, AND IMPLICATIONS OF THE DISPERSAL OF BELCHER ISLAND ERRATICS

Victor K. PREST, Geological Survey of Canada, 601 Booth Street, Ottawa, Ontario K1A 0E8.

ABSTRACT This paper deals with the evolution of ideas concerning the configuration of flow patterns of the great inland ice sheets east of the Cordillera. The interpretations of overall extent of Laurentide ice have changed little in a century (except in the Arctic) but the manner of growth, centres of outflow, and ice-flow patterns, remain somewhat controversial. Present geological data however, clearly favour the notion of multiple centres of ice flow. The first map of the extent of the North American ice cover was published in 1881. A multi-domed concept of the ice sheet was illustrated in an 1894 sketch-map of radial flow from dispersal areas east and west of Hudson Bay. The first large format glacial map of North America was published in 1913. The binary concept of the ice sheet was in vogue until 1943 when a single centre in Hudson Bay was proposed, based on the westward growth of ice from Labrador/Québec. This Hudson dome concept persisted but was not illustrated until 1977. By this time it was evident from dispersal studies that the single dome concept was not viable. Dispersal studies clearly indicate long-continued westward ice flow from Québec into and across southern Hudson Bay, as well as eastward flow from Keewatin into the northern part of the bay. Computer-type modelling of the Laurentide ice sheet(s) further indicates their complex nature. The distribution of two indicator erratics from the Proterozoic-age Belcher Island Fold Belt Group help constrain ice flow models. These erratics have been dispersed widely to the west, southwest and south by the Labrador Sector of more than one Laurentide ice sheet. They are abundant across the Paleozoic terrain of the Hudson-James Bay lowland, but decrease in abundance across the adjoining Archean upland. Similar erratics are common in northern Manitoba in the zone of confluence between Labrador and Keewatin Sector ice. Scattered occurences across the Prairies occur within the realm of south-flowing Keewatin ice. As these erratics are *not* known, and presumably not present, in Keewatin, they indicate redirection and deposition by Keewatin ice following one or more older advances of Labrador ice. The distribution of indicator erratics thus test our concepts of ice sheet growth.

RÉSUMÉ *Historique des modes d'écoulement de l'Inlandsis laurentidien et incidences de la dispersion des blocs erratiques de l'archipel de Belcher.* On traite ici de l'évolution de la pensée en ce qui a trait à la configuration des grands mouvements glaciaires continentaux à l'est de la Cordillère. Les interprétations quant à l'étendue de l'Inlandsis laurentidien ont peu changé depuis un siècle (sauf pour l'Arctique), mais les questions sur la croissance, les centres de dispersion et l'écoulement glaciaire demeurent quelque peu controversées. Les données géologiques actuelles, toutefois, tendent à confirmer la notion de centres d'écoulement multiples. La première carte montrant l'étendue de la couverture glaciaire sur l'Amérique du Nord a été publiée en 1881. Le concept d'un inlandsis à dômes multiples a été illustré dans une carte de 1894 montrant l'écoulement radial à partir de zones de dispersion à l'est et à l'ouest de la baie d'Hudson. La première grande carte glaciaire de l'Amérique du Nord a été publiée en 1913. Le concept d'un inlandsis binaire a prévalu jusqu'en 1943, alors qu'on a mis de l'avant l'idée d'un seul centre dans la baie d'Hudson, en se fondant sur la croissance glaciaire vers l'ouest à partir du Québec-Labrador. Ce concept du dôme hudsonien a persisté, mais n'a pas été illustré avant 1977. Or, il apparaissait d'ores et déjà à partir des différentes études menées sur la dispersion des glaces que la thèse du dôme unique n'était pas juste. Les études sur la dispersion font état d'un écoulement glaciaire continu vers l'ouest, dans la partie sud de la baie d'Hudson et au delà, à partir du Québec, ainsi qu'un écoulement vers l'est dans la partie nord de la baie, à partir du Keewatin. La modélisation par ordinateur de l'Inlandsis laurentidien démontre bien la complexité des écoulements glaciaires. La répartition de blocs erratiques indicateurs du groupe de la zone de plissements d'âge protérozoïque de l'archipel de Belcher aide à préciser les modèles d'écoulement glaciaire. Ces errratiques ont largement été dispersés vers l'ouest, le sud-ouest et le sud à partir du secteur labradorien lors de plusieurs avancées de l'Inlandsis laurentidien. Ils sont abondants dans les terrains paléozoïques des basses terres des baies de James et d'Hudson, mais moins nombreux à travers les hautes terres archéennes adjacentes. Des blocs erratiques semblables sont courants dans le nord du Manitoba dans la zone de confluence des glaces du Labrador et du Keewatin. On trouve des blocs dispersés à travers les Prairies dans la zone d'écoulement des glaces du Keewatin vers le sud. En raison de leur absence probable au Keewatin, ont croit qu'il y aurait eu un changement de direction des glaces du Keewatin et dépôt seulement après une ou plusieurs avancées glaciaires antérieures en provenance du Labrador. La répartition des blocs erratiques indicateurs aide à éprouver les différents concepts sur la croissance de l'inlandsis.

Manuscrit reçu le 18 janvier 1989; manuscrit révisé accepté le 25 novembre 1989

INTRODUCTION

The theory of continental glaciation was slow in gaining acceptance in North America but the widespread distribution of foreign stones was instrumental in its ultimate recognition. This overview of Laurentide ice masses deals mainly with the various concepts for which sketches or maps were published illustrating evidence of continental glaciation. Emphasis is placed on the Canadian data and this data illustrates the importance of foreign or erratic indicators in reconstruction of ice-flow patterns.

The figures herein are varied-scale reductions of figures, diagrams, plates and maps appearing in the literature. This paper also provides some background data that led to the concepts presented by various authors, whether or not appropriate sketches were forthcoming. And in the context of changing concepts there is some discussion as to the ice cover over the Queen Elizabeth Islands, the northern part of the Appalachian Mountains, and the Hudson and Ungava basins. For a comprehensive account of the beginning of glaciology and changing concepts as regards both mountain and continental ice in Europe and North America, the reader is referred to Carozzi (1984). Brief historical accounts are to be found in Flint (1943, 1947 and 1957). Also the matter of changing concepts and drift dispersal in the Hudson-James Bay lowlands is succintly dealt with by Shilts (1980).

Louis Agassiz' account of widespread glaciation in Europe was slowly gaining adherents in North America during the late 1830's. Perhaps the first published support of any consequence in North America was that of Timothy Conrad (1839). He favoured a period of 'refrigeration' and consequent development of ice masses to account for the occurrence of far-travelled boulders (sliding across frozen lakes), and also the occurrence of boulder fields developed over their own bedrock sources. But the Agassiz concepts of inland glaciation was first clearly reported as applicable in North America by Edward Hitchcock (1841), though for some years thereafter he expressed certain doubts. The ice-berg concept, where the land was submerged beneath the sea, was still the vogue of the day.

The first evidence of inland glaciation in Canada stems from the 1845 field observations of Wm. Logan (1847). The year before Louis Agassiz came to North America, Logan had clearly described the work of a glacier in the Lake Timiskaming basin of Northern Ontario. He hypothesized a major glacier entering the basin from the low Archean terrain farther north, with subsidiary glaciers from the east. He noted that the striae and grooves along the lake shores continued directly across large promontories projecting into the lake. He clearly differentiated between this glacial phenomenon and the work of shore ice. And he reported that a gigantic ridge of sand and gravel, forming the narrows halfway down the lake, was an eroded remnant of a moraine. (It is unbelievable that Logan's report went unnoticed by others involved in the glacial dispute.) Furthermore, in Logan's great volume on the 'Geology of Canada' (1863) summarizing the work of the Geological Survey from 1842 to 1863 he included an account of the 'Superficial geology'. He reported that "Rounded, grooved, and polished surfaces are often found on the older rocks — the processes that produced these results must therefore have been contemporaneous with the transport of the drift over the surface — the evidences afforded in Canada appear to favour the supposition that they have been caused by the action of glaciers."

Thereafter many explorer geologists contributed to our understanding of the great inland ice sheets, though this was secondary to their investigations of the bedrock formations and even the flora and fauna. Notably among these contributors were Robert Bell, A.P. Low, Sir Wm. Dawson, George Dawson, Robert Chalmers and Joseph Tyrrell. Ice-flow directions were recorded and moraines and shorelines noted. In the following account the terms Laurentide ice and Laurentide ice sheet are used in referring to any inland ice sheet, regardless of its age, stemming from the Laurentian region of Canada, whereas Laurentide Ice Sheet [capitalized] refers specifically to the latest or Wisconsinan ice sheet. It was thus applied by Flint (1947, p. 215-245; 1957, p. 302, 306, 313-318). This usage is also followed by the Geological Survey of Canada (Prest, 1970, p. 705-706). At its full development it was comprised of three mutually independent though mainly confluent ice masses-the *Keewatin, Labrador* and *Baffin sectors* (Dyke and Prest, 1987).

Please note that single, or double square brackets are employed where I have added words, phrases or notes for clarification purposes.

THE EARLY DEFINITIVE WORK
(Naming of the ice masses and early sketch maps)

Our concept of a great glacier flowing westward and southwestward over northern Ontario, Manitoba, and onto the Prairies, stems from the basic data provided by Logan (1847, 1863) and Bell between the years 1865 and 1886. It is of historical interest here that a coloured map of the 'Superficial deposits between Lake Superior and the Gaspé' was compiled by Robert Bell in 1865. This 'materials map' was part of a series of geological maps that were to accompany Logan's great volume on the Geology of Canada (1863). This fine map of the superficial deposits [not reproduced herewith] was clearly the fore-runner of Canada's surficial geology map coverage. The first *Glacial Map of Canada* was that of Wm. Dawson (1872) (Fig. 1). It encompassed the area from western Lake Superior to the Atlantic, and included the Island of Newfoundland. Glacial striations showing the direction of ice flow are indicated over this vast area.

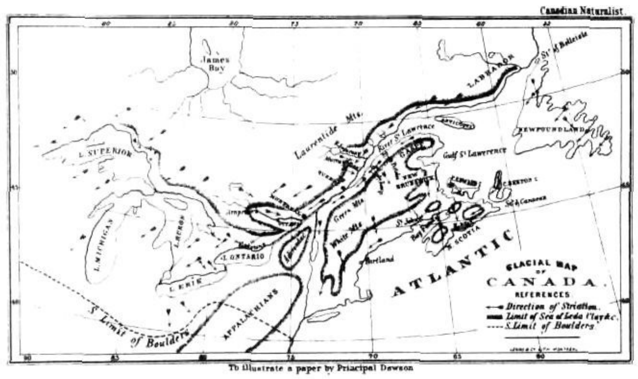


FIGURE 1. Glacial map of Canada (J. W. Dawson, 1872).
Carte glaciaire du Canada (J. W. Dawson, 1872).

The first sketch map of the 'North American Glacier Cover', however, was that by Wm. Morris Davis (*in* Shaler and Davis (1881, plate XXV) (Fig. 2). This shows an ice cover over most of Canada east of the Cordillera including all the then known Arctic Islands and parts of the northern United States. Despite the small size of the published plate, some ice-flow lines are shown in the southern part of the ice cover. It is obvious that Davis was not a believer in the then popular concept of ice flow from the polar region, nor in the 'diluvial' theory. A larger, page-size map entitled 'Map of Eastern North America' was inserted in the Shaler and Davis volume to better illustrate the better-known southeastern margin of the ice sheet, the Wisconsin driftless area, and the "course of motion of the ice". This map was compiled by C.H. Hitchcock (1878) for the State of New Hampshire. Though dealing with only a part of the ice cover [as was Dawson's map] it is reproduced here (Fig. 2a) in view of its early date and fine detail. Both the sketch and the larger map are remarkably accurate portrayals for that early period.

In 1886 Bell explored the lower parts of the Albany and Attawapishkat [Attawapiskat] rivers in northern Ontario and noted the regional southwestward trend of glacial striations. He also noted the abundance of greywacke erratics from the Proterozoic formations of southeastern Hudson Bay, including those with calcareous concretions "— up to the size of cricket balls" (Bell, 1886). [This matter will be dealt with in the second part of this present paper.]

In 1887 A.P. Low examined James Bay and the region east of Hudson Bay, and drawing on both his own and Bell's observations reported that "— the continental glacier flowed down from the highland on the east side of the bay, crossed it and had momentum and thickness sufficient to push itself in a direction south of west up the west side [of the bay] over the wide margin of the flat deposits of limestone [Paleozoic] and then over the higher Archean country that forms the water shed [at about 300 m elevation] between Hudson Bay and the Great Lakes" (Low, 1888, p. 61J). He also identified a major moraine down the length of James Bay that was constructed during the retreat of his continental glacier. [This moraine is now recognized as part of the Harricana Moraine.] It is clear that Low envisaged ice flowing toward the west during both the advance and retreat of his *continental ice*, — a concept that remains valid to this day.

During the years 1887-90 J.B. Tyrrell (1892) made extensive surveys in northern Manitoba and Saskatchewan. He postulated that "— a great snow field appears to have formed in the country around and to the north and east [more correctly north-northeast] of Reindeer lake and ice appears to have flowed in great glaciers westward through the basin of Lake Athabasca, southward across the Plains, and southeastward up the valley of the ancient river of the Winnipeg basin" [the Red River Valley] (Tyrrell, 1892, p. 216E).

At the same time G.M. Dawson (1887) from his own field work in 1886 and R.G. McConnell's observations in 1887 (1891) in northwest Canada east of the Rockies, and the reports of explorers along the Arctic coast, together with the reports of Bell and Low (idem) in eastern Canada, accepted the concept of a 'continental glacier'. He stated "— the facts so far developed in this northern part of the continent point to a movement of ice outward in all directions from the great Laurentian axis or plateau which extends from Labrador around the southern extremity of Hudson Bay [and thence northwest] to the Arctic Sea, rather than to any general flow of ice from the vicinity of the geographic pole southward". Shortly thereafter, Dawson (1891) realized that the term 'continental glacier' was not appropriate when there were two dynamically separate, though partly confluent ice masses in the northwest — one in the Cordillera and the other east of it. He therefore stated

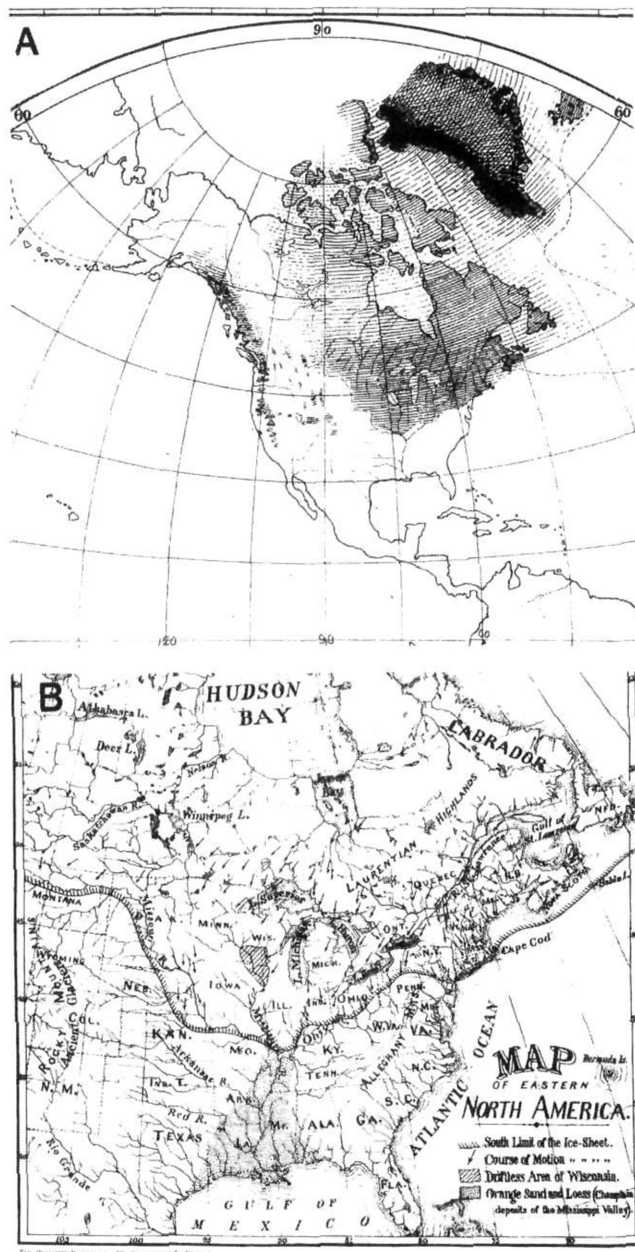


FIGURE 2. A. The past and present distribution of glaciers (Shaler and Davis, Pl. XXI, 1881). B. Map of eastern North America (Hitchcock, 1878; part of Pl. XX, *in* Shaler and Davis, 1881).

A. Les répartitions actuelle et passée des glaciers (Shaler et Davis, pl. XXI, 1881). B. Carte de l'est de l'Amérique du Nord (Hitchcock, 1878; partie de la pl. XX, in *Shaler and Davis, 1881).*

that the "— eastern *mere de glace* may appropriately be named the great Laurentide Glacier while its western fellow is known as the Cordilleran Glacier". He thus coined the basic terms *Laurentide* and *Cordilleran glaciers* [currently known as ice sheets]. Dawson, however, did not produce a sketch map of his Laurentide ice mass.

In 1894, T.C. Chamberlin produced his 'Ideal map of North America during the Ice Age'. This was included in Chamberlin's chapter in James Geikie's comprehensive book on the Great Ice Age. This circular-pattern sketch map (Fig. 3) clearly shows the spheres of influence of the Keewatin and Labrador ice. Note also the locations of the southern ice margin, the Wisconsin 'driftless area', suggested nunataks? in New Brunswick, Maine and over the Adirondacks, and the separate ice on the island of Newfoundland. Chamberlin's chapter in 'The Great Ice Age' also includes a more detailed coloured map of 'The Southern part of glacial deposits of the United States and Canada' Plate XV [not reproduced herewith.] Like Bell's coloured map this was a great contribution to the knowledge of those times.

In 1895 Warren Upham included a page-size, green-coloured map of the North American ice-covered areas in his fine report on the Glacial Lake Agassiz (Fig. 4). This map of the ice cover is unique in that it not only identifies the Cordilleran and Laurentide ice sheets but also shows the territorial boundaries of that day. [As far as I am aware this is the only map that clearly labels the Laurentide Ice Sheet for the next 80 years (see Ives *et al.*, 1975, figure 1).]

Meanwhile, great advances in our understanding of glacial matters were being made in the Maritimes. Robert Chalmers, unlike all earlier observers, was specifically engaged over many years in the geological study of the 'surface deposits' of New Brunswick and adjacent regions. He first reported on a local north-flowing glacier into the Baie des Chaleurs area (1883). Later in several reports for the Geological Survey of Canada between 1885 and 1895 he noted the dominant influence of topography on the direction of ice flow of a major glacier mass centred over the Appalachian Highlands: whereas the ice had flowed generally southward in the St. John River system, it had flowed east and northeast across central and eastern New Brunswick, on either side of the drainage divide.

Chalmers was also aware, however, that at an earlier, maximum stage of glaciation the ice had flowed southeastward across the Caledonia Highlands into and across Bay of Fundy and onward over Nova Scotia to the Atlantic Ocean. He confirmed the south and southeast ice-flow trends over southwestern New Brunswick as earlier reported by others. He found evidence of both early (advance) and late (recessional) ice flow from the Appalachian Highlands, and from the Notre Dame

FIGURE 3. Ideal map of North America during the ice age (Chamberlin, Pl. XIV, *in* Geikie, 1894).

Carte glaciaire idéale de l'Amérique du Nord pendant l'âge glaciaire (Chamberlin, pl. XIV, in *Geikie, 1894).*

FIGURE 4. Map showing the relationship of Lake Agassiz to the drift-bearing area of North America, and to lakes Bonneville and Lahontan (Upham, Pl. 2, 1896).

Carte de l'Amérique du Nord montrant les relations entre le Lac Agassiz et la zone couverte de dépôts glaciaires et les lacs Bonneville et Lahontan (Upham, pl. 2, 1896).

Mountains of Québec, toward the St. Lawrence River. Though he accepted Low's 'continental ice' as having crossed the St. Lawrence Valley he surmised that Laurentide ice may have invaded Maine and southwestern New Brunswick, but he could find no evidence elsewhere of its direct invasion beyond northern parts of the province. [Chalmers observations are assuredly in-keeping with modern day deductions as to the complexity of the ice cover (see Rampton *et al.*, 1984; Kite *et al.*, 1986).]

In summarizing his 1890-93 field observations Chalmers stated "— at the period of maximum extension of the ice, there was a general radial movement from the main *nevé*-ground of the northeast Appalachians, northward and eastward into the St. Lawrence Valley, eastward into the southwestern embayment of the Gulf of St. Lawrence, southeastward into the Bay of Fundy and Atlantic Ocean, and southward and southwestward in United States territory" (1895, p. 106M).

Throughout Chalmer's accounts he stresses the *possible* effects of debris-laden floating ice masses, rather than glacier ice, as responsible for the diversity of fine striations below the limit of marine overlap [see Glacial Map of Canada, Prest *et al.*, 1968]. He thought that the glacial cover in western New Brunswick did not exceed 2000 feet in thickness and thinned rapidly toward Gulf of St. Lawrence and Bay of Fundy where it dissipated in the sea: wind, waves and tides then drove pack-ice over the lowlands resulting in various patterns of crossing striae. Following hurried trips to Prince Edward Island and the Magdalen Islands he reported that the last ice sheet had reached only to the western part of the former and did not reach the latter. [[There is evidence that at some time New Brunswick based ice did flow eastward over Prince Edward Island, and only later did active ice flow southwestward from its central uplands into Northumberland Strait, and also south and southwest from Gulf of St. Lawrence into Malpeque Bay (Prest, 1973). The Magdalen Islands were not covered by the last ice sheet (Prest, 1957, 1970; Prest *et al.*, 1976), but earlier ice did cross the islands contorting the soft Carboniferous rocks and depositing a clayey till (Dredge and Grant, 1987). Most of our modern observations and deductions are readily incorporated in Chalmers history of events.]]

In 1893-94 Tyrrell expanded his work west of Hudson Bay in the District of Keewatin, and in two G.S.C. Annual Reports (1896, 1897) and in an outside paper (1898) applied the name *Keewatin Glacier* to the vast ice mass that lay northwest of Hudson Bay and was the most northerly of the three great regions of glaciation — the Cordilleran, the Keewatin, and the *Labradorean*. He applied the latter name to the ice mass centred in [what is now] central Québec/Labrador. He made no mention of Dawson's Laurentide Glacier for the confluent Keewatin/Labradorean ice mass, nor Upham's term Laurentide ice sheet.

In Tyrrell's report of 1897 (p. 178F) he introduced a sketch map showing three positions successively occupied by the centre of the Keewatin Glacier (Fig. 5). The sketch indicates a major shift in the centre of flow of the last ice sheet from northwest of Doobaunt [Dubawnt] Lake toward the southeast, with the centre of the last remnant situated on a part of what is currently regarded as the Keewatin Ice Divide. [This term was formerly introduced by H.A. Lee (1959) though in use at the

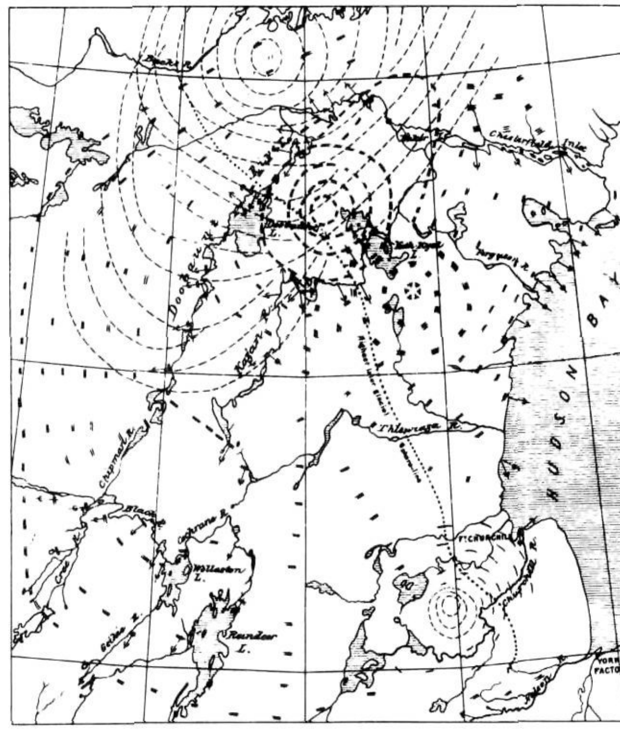
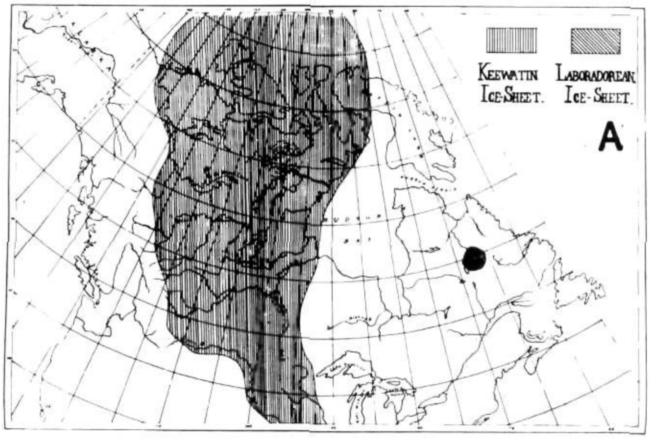


FIGURE 5. Diagram showing three positions successively occupied by the centre of the Keewatin Glacier (Tyrrell, Diagram 621, 1897).

Diagramme montrant les trois positions occupées successivement par le centre du glacier du Keewatin (Tyrrell, diagramme 621, 1897).

Survey prior to that time. Tyrrell's sketch also shows a fourth but unrelated centre southwest of Churchill, Manitoba. This may be readily mistaken for his third centre, and there is scant reference to it in the text.]

In 1898 Tyrrell produced three sequential sketch-maps purporting to show the development and decay of Cordilleran, Keewatin, and Labradorean glaciers proceeding from west to east. In the case of the ice mass east of the Cordillera — the Keewatin Glacier reached its full development as the Labradorean glacier was first forming, and it receded to about one third its size as the Labradorean glacier grew to its maximum (Fig. 6). Tyrrell's concepts were probably influenced by Dawson's report (1891) that Keewatin Glacier was intermediate in time as well as in position between the Cordilleran and Labradorean glaciers. But Tyrrell had also noted that north of Churchill the Keewatin Glacier had flowed eastward into Hudson Bay whereas south of Churchill it had flowed generally southward until it gave place to younger, west-flowing Labradorean ice. It is somewhat surprising that his Plate VI does not show any Labradorean ice in northern Hudson Bay, Davis Strait, the Torngat Mountains, Newfoundland nor the Maritimes, in view of the observations of some of his colleagues. The sequential growth and decay from west to east was not generally accepted though in later years it appears to have mislead A.P. Coleman (1926) and Charles Keyes (1935). It is certainly not in keeping with our current concepts of Late Wisconsinan confluent, though locally shifting, Keewatin and Labradorean ice in Manitoba. In any case before the end of the 19th Century the Cordilleran and Laurentide ice sheets had



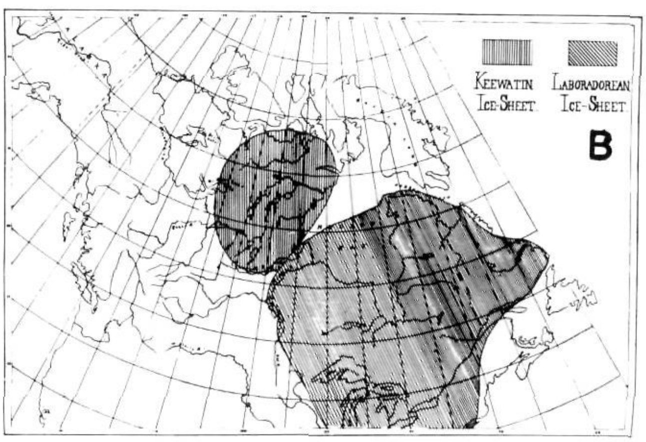


FIGURE 6 A. Keewatin Ice Sheet Maximum (Tyrrell, Pl. V, 1898). B. Labradorean Ice Sheet maximum (Tyrell, pl. VI, 1898).

A. Maximum de l'indlandsis du Keewatin (Tyrrell, pl. V, 1898). B. Maximum de l'inlandsis du Labrador (Tyrell, pl. VI, 1898).

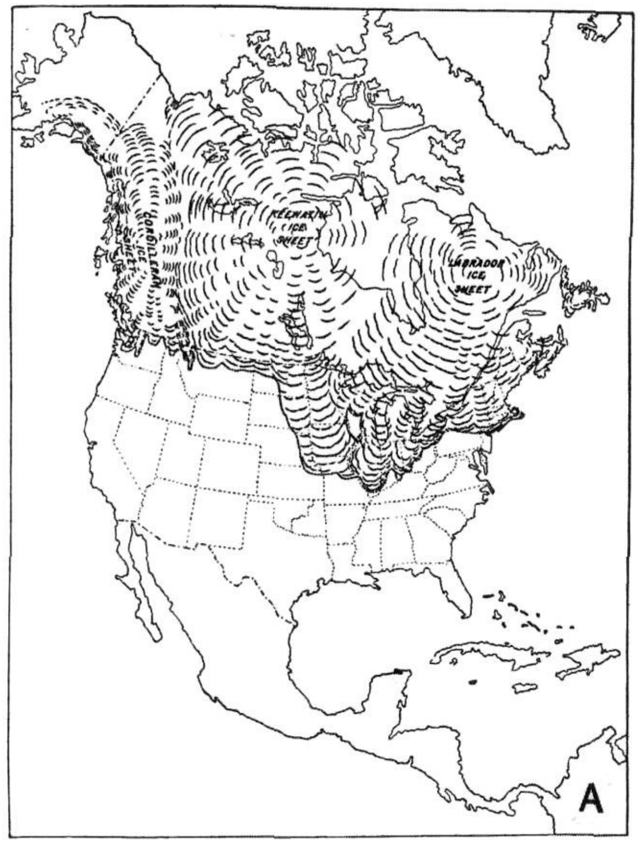


FIGURE 7a. Sketch-map showing the North American area covered by ice at the maximum stage of glaciation (Chamberlin, *in* Chamberlin and Salisbury, Fig. 469, 1907) (essentially same as Fig. 3 above).

Carte montrant la partie englacée de l'Amérique du Nord à l'optimum glaciaire (Chamberlin, in *Chamberlin et Salisbury, fig. 469, 1907) (à peu près pareille à la fig. 3).*

been identified and variously named, and the latter was shown to be comprised of two distinct parts, the Keewatin and Labradorean ice masses; it was not commonly viewed as a unified entity. The Foxe-Baffin ice had not been recognized as a centre of outflow though Wm. Morris Davis had earlier shown Baffin Island as a separate ice-covered entity (Fig. 2b).

THE TWENTIETH CENTURY (Sketch maps)

Though the groundwork as to the extent and concepts pertaining to the North American ice cover had been laid in the latter half of the 19th Century, it was not until 1907 that an adequate portrayal of the ice-flow trends *in toto* was forthcoming. In the account on the Pleistocene or glacier period, T.C. Chamberlin (1907), included both a circular-pattern sketch (Figure 469) and an ice-flow trend map (Figure 470). The former is essentially the same as his 1894 sketch but with Keewatin ice somewhat expanded at the expense of Labrador ice. This sketch is historically important in that the Keewatin and Labrador ice sheets, as well as the Cordilleran ice sheet, are named thereon (Fig. 7a). Figure 470 marks a major departure and advance in the portrayal of the ice; it shows the striae from crucial areas as recorded in the literature from which Chamberlin adroitly deduced his ice-flow trend lines (Fig. 7b).

Chamberlin refers to the three centres of glaciation as Labrador, Keewatin and Cordilleran and to these ice masses as *ice sheets* — the first such reference, though conceptually not different from Tyrrell's three glaciers. He made no mention of Dawson's Laurentide Glacier nor Upham's Laurentide Ice Sheet, though he surmised that Keewatin and Labrador ice sheets were confluent in Hudson Bay. Like Tyrrell, he noted that the Keewatin Ice Sheet had advanced westward 800 to 1000 miles from a low, flat, central area whereas, as noted by Dawson, the east-flowing Cordilleran Ice Sheet had reached only to the Alberta Foothills. Chamberlin deduced that there must have been differences in the precipitation on the different sides of the ice sheets, and hence an influence of this on their surface topography, as well as differences in their temperature and mobility. Chamberlin (1913) was also responsible for the first large 'Glacial Map of North America' (Fig. 8). Except for the unfortunate portrayal of ice flow outward from the Richardson Mountains in Yukon Territory and extending westward over the unglaciated terrain in the Yukon, this is remarkably accurate portrayal of the then known directions of ice flow.

FIGURE 7b. Map showing the glaciated area of North America (includes striae and ice flow trend lines) (Chamberlin, *in* Chamberlin and Salisbury, Fig. 470, 1907).

Carte montrant la partie englacée de l'Amérique du Nord (incluant les directions de l'écoulement glaciaire et des stries) (Chamberlin, in *Chamberlin et Salisbury, fig. 469, 1907)*

For some unknown reason neither of Chamberlin's maps received the attention and the acclaim they assuredly merited.

Tyrrell (1913a), on the basis of some diverse-trending striae in the Patricia area of northwestern Ontario, suggested another centre of outflow that he referred to as a Patrician glacier (Fig. 9). This gave some credence to Dawson's original concept of the Laurentide Glacier, but as field evidence was sparse the centre in northern Ontario received but scant acceptance. And so for several decades the concept of two separate, radially-flowing ice sheets, Keewatin and Labradorean, held sway.

In 1914 Lawrence Martin (University of Wisconsin) produced the first of his sketch maps in the textbook College Physiography (Fig. 172, *in* Tarr and Martin, 1914). This figure shows each of the Arctic Islands with their own ice caps, and indicates that Keewatin ice flowed southward in the western part of Hudson Bay, continued on over eastern Manitoba and western Ontario (Fig. 10) — a picture quite unlike the preceding Chamberlin maps. It also extended Keewatin ice eastward over Southampton Island and Melville Peninsula. This map was

FIGURE 8. Map of North America during the Great Ice Age (Chamberlin, 1913).

Carte de l'Amérique du Nord pendant le Grand Âge glaciaire (Chamberlin, 1913).

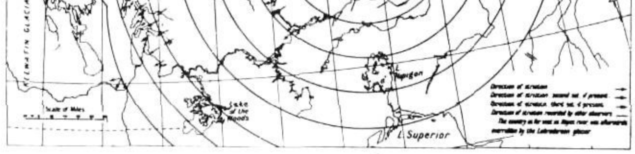


FIGURE 9. Original map of Patrician ice centre (Tyrrell, Pl. 1, 1913).

Carte originale du centre du glacier de Patricia (Tyrrell, pl. 1, 1913).

reproduced again in the Physical Geography of Wisconsin (Martin, 1916), with a somewhat enlarged and bull's-eyed (blackened) driftless area. The 1916 map, but with a white driftless area, appeared again in the well known Textbook of geology, Part 2, by Pirsson and Schuchert (1924, Fig. 227). [Note that the North America ice cover as shown in the 'World Map of Pleistocene Glaciation' (Fig. 226 in this same publication)

FIGURE 10. Territory covered by the maximum extension of the glaciers in North America; North America during the Glacial Period (Martin *in* Tarr and Martin, Fig. 172, 1914; Martin, Fig. 27, 1916).

Territoire englacé de l'Amérique du Nord à l'optimum glaciaire; l'Amérique du Nord pendant la période glaciaire (Martin in *Tarr et Martin, fig. 172, 1914; Martin, fig. 27, 1916).*

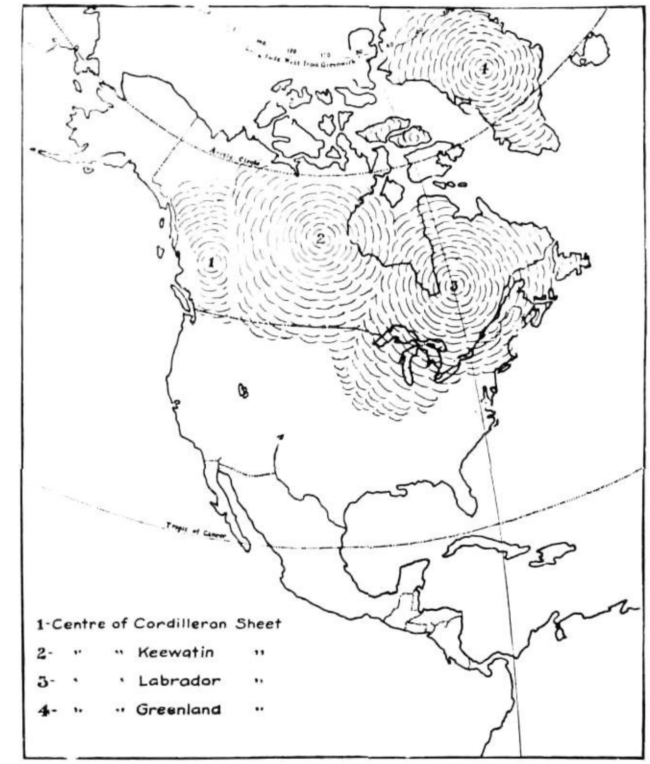


FIGURE 11. Glacial map of North America (Coleman and Parks, Fig. 188, 1922).

Carte glaciaire de l'Amérique du Nord (Coleman et Parks, fig. 188, 1922).

does not show an ice cover over the Arctic Islands nor ice in western Hudson Bay.] In their textbook on 'Elementary Geology', Coleman and Parks (1922a) produced a simple circular-pattern map indicating the spheres of influence of the North American ice cover (Fig. 11); but with the centres of both Keewatin and Labrador ice misplaced, and all the North American ice sheets numbered from west to east probably as a result of Dawson and Tyrrell's earlier reports. The same year Coleman's report on the Gaspé was published (1922b). He drew attention to the importance of local ice in that region.

The profusion of ice-flow features indicative of the southeast flow of ice over all of southeastern Nova Scotia, together with *the evidence of south and southeast flow in New Brunswick* into Bay of Fundy, led to the concept of Laurentide ice sweeping over the entire Maritimes region. Goldthwait (1924) stated "— direct proof exists that the ice sheet filled the Gulf of St. Lawrence and the Bay of Fundy and covered the banks off the south coast of the province." [[Though the matter is still debated, the preponderance of field data favours more locally-derived Appalachian ice rather than Laurentide ice over the Maritimes. The limit of Laurentide (Labrador Sector) ice *per se* may thus be in the Gaspé and northern New Brunswick much as envisioned by Chalmers and Coleman. In regard to the history and theories pertaining to Gaspésie, a paper by McGerrigle (1952) is of prime importance. For a comprehensive *report on all aspects of the Gaspésie glaciation, see David and* Lebuis (1985). And details of the northeastern end of the Gaspé Peninsula are reported by Veillette (1988).]]

In 1924 W. C. Alden (USGS) produced a circular-pattern map indicative of radial flow that was somewhat more refined than earlier sketch maps of this kind (Fig. 12). [This is the sketch map that was used by A. P. Coleman in his 'Ice Ages Recent and Ancient' (1926).] Alden's map shows confluent ice in Hudson Bay but an open Hudson Strait, Keewatin ice as extending as far as Viscount Melville and Lancaster sounds and, incorrectly, over Foxe Basin and western Baffin Island, but no ice on the remaining Arctic Islands. Coleman (1926, p. 14) drawing on Tyrrell's work in Keewatin, concluded that the ice sheets were separate entities rather than "...parts of a supposed Laurentide ice sheet covering the Laurentian region of Canada", thus disagreeing with Dawson and Upham.

In 1932 in the 'Physical Geography of Wisconsin' (Fig. 27, p. 85) Martin reintroduced his earlier map, with its blackened driftless area, but without the ice caps on most of the Arctic Islands nor the Keewatin ice-flow lines in western Hudson Bay (Fig. 13). But he incorrectly placed the northern limit of Keewatin ice on southern Victoria Island and across Boothia Peninsula. He indicated the Patrician glacier in northwestern Ontario and showed the striae evidence as reported by Tyrrell.

In 1935 in symposium articles on the 'Patrician Center of Glaciation' published in 'Pan-American Geologist' [where Tyrrell is erroneously referred to as John], Tyrrell's notes and

FIGURE 12. Map showing area covered by the great ice sheets in North America at their maximum extension and the centres of ice accumulations (Alden, Fig. 5, 1924).

Carte montrant la région couverte par les grands inlandsis au moment de leur étendue maximale en Amérique du Nord et les centres d'accumulation de glace (Alden, fig. 5, 1924).

FIGURE 13. North American glaciated regions (Martin, Pl. II, 1932, 1935).

Les régions englacées de l'Amérique du Nord (Martin, pl. II, 1932, 1935).

'circle' diagram served as an introduction to the invited papers. The various speakers both questioned and accepted the concept of Patrician ice. Martin (1935, Plate ii) again used his 1932 sketch map retaining his ice-flow lines across northwestern Ontario and northeastern Manitoba, and his Keewatin limit in the north. [Neither of these concepts are in accord with presently known geological data.] The sketch maps produced for the Symposium by Keyes (1935, plates iii, xii, xiii, xiv) are purely hypothetical concepts.

In 1940 W.W. Atwood presented an interesting ice flow map [not reproduced herewith] showing the Keewatin, Patrician, and Labrador ice caps over the Laurentian Shield and a probable major ice cap over all the Arctic Islands, except perhaps Banks Island. The map indicates an 'open' Foxe Basin, Hudson Strait and the eastern part of Hudson Bay. A separate small ice cap is shown over the island of Newfoundland.

In an excellent, comprehensive account of the Pleistocene glaciation of Québec, MacLean (*in* Dresser and Denis, 1944, p. 487-527) dealt with the development and migration of the Labrador ice sheet and produced a sketch map based on the reports of Low (1888, 1889, 1902). This sketch shows the northwestward migration of the centre of dispersal in north-central Québec. It also shows the zone of confluent Labrador and Keewatin ice in the Hudson Bay region much as we interpret it today (Fig. 14).

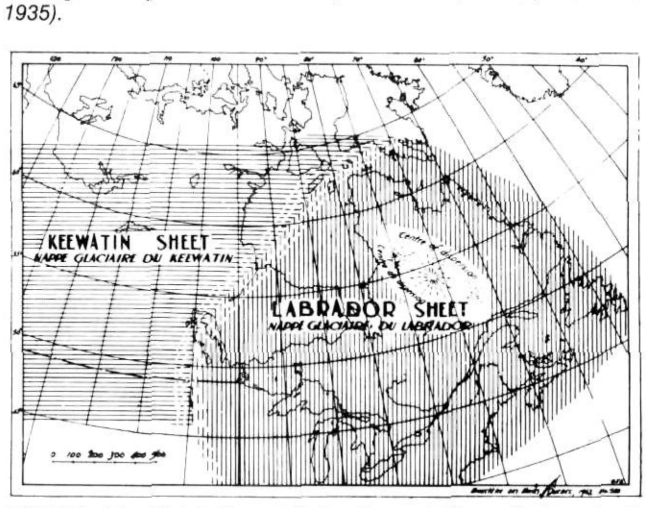


FIGURE 14. Distribution of Labrador and Keewatin ice sheets (MacLean, Fig. 35, p. 495, *in* Dresser and Denis, 1944).

Répartition des inlandsis du Labrador et du Keewatin (MacLean, fig. 35, p. 405, in *Dresser et Denis, 1944).*

The problem of growing a great ice sheet over the low-lying Keewatin region has remained to haunt geologists and others for many years. R.F. Flint, after much thought, concluded that glacier ice in Keewatin was an outgrowth of an expanding ice sheet lying to the northeast and east (Flint, 1943; 1947,

p. 233-236). He postulated that as the Pleistocene climates cooled from nonglacial to glacial conditions, mountain or valley glaciers developed in the highlands along Canada's east coast [mainly Baffin Island and Labrador]; these expanded into piedmont glaciers on lower lands to the west and southwest. The leading edge of the expanded glaciers became a secondary topographic barrier and received snowfall at the expense of the so-called mountains to the northeast, until the latter were buried and no longer either a topographic or meteorologic factor. Building on the concept of his friend Max Demorest (1943), with extension flow giving place to extrusion flow during the piedmont phase, he was able to envisage a major ice sheet advancing into the Hudson basin and then expanding rapidly southward, westward and northwestward. He re-introduced the name 'Laurentide ice sheet' for all Pleistocene ice masses with a centre of outflow over Hudson Bay. He considered the radial flow patterns of Keewatin and Labradorean ice masses to be relatively short-lived recessional phenomena even though he was aware of Tyrrell's major shifting centres in Keewatin and sustained outflow from southern Hudson Bay. [He explained the latter as due to the exceptional thickness of the ice in the basin. Unfortunately no small sketch map was produced to illustrate the Hudson basin ice sheet with its centre over the basin].

In 1945 the monumental 'Glacial Map of North America' was published, by the Geological Society of America, with R.F. Flint as chairman of a group of American and Canadian geologists sponsored by the National Research Council in Washington[1]. This glacial map stimulated both work and thought regarding the ice sheets and their growth.

In 1947 Wickenden (GSC) produced a simplified sketch map showing only the major ice-flow trends, and omitted the Patrician centre. This sketch unfortunately did not show the eastward ice flow from Keewatin nor any ice on Baffin Island, and only a much generalized flowline across Victoria Island (Fig. 15). In 1947 Flint's book on 'Glacial Geology and the Pleistocene Epoch' was published; his Plate 3 of 'the principal areas covered by glacier ice in the Northern Hemisphere' [not reproduced herewith] portrays an ice cover that includes all of the Arctic Islands.

As an outgrowth of the preparatory work on the 'Glacial Map of Canada' (Wilson *et al.*, 1958), Prest produced a sketch map (1957, Fig. 81), showing ice-flow trends (Fig. 16), but like earlier sketches it also, incorrectly, showed eastward flow over Melville Peninsula whereas the main regional flow is now known to be westward out of Foxe Basin (Sim, 1960). Both the 1957 sketch map and the larger 1958 'Glacial Map of Canada' indicate limited ice on Banks Island and on the western Queen Elizabeth Islands. Fyles (Craig and Fyles, 1960) reported that this glacial 'limit' should be farther east on Banks Island, and that it was a Wisconsin glacier limit (see footnote p. 16 in Legget, 1961). This has since been confirmed (Vincent, 1983). Thus the 1957 sketch map (figure 81) was reproduced with an adjusted ice limit on Banks Island and in Parry Channel, and with a few added striations (Prest *in* Legget, 1961, Map 1 [not reproduced herewith]. It is clear that by 1957 the northern limit of the Late Wisconsinan Laurentide Ice Sheet was considered to be in Parry Channel. Also in 1957 J.D. Ives introduced the concept of 'instantaneous glacierization' as a more feasible and logical

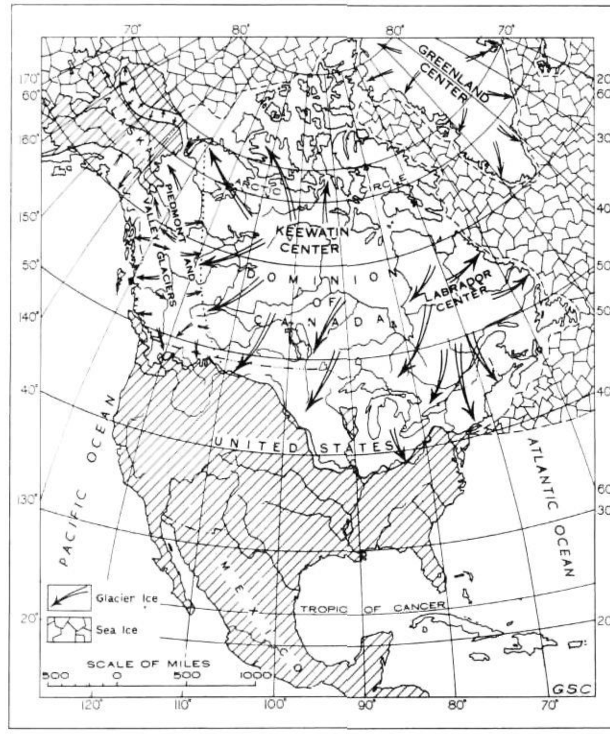


FIGURE 15. Pleistocene glaciation in North America (Wickenden, Fig. 76, 1947).

La glaciation du Pléistocène en Amérique du Nord (Wickenden, fig. 76, 1947).

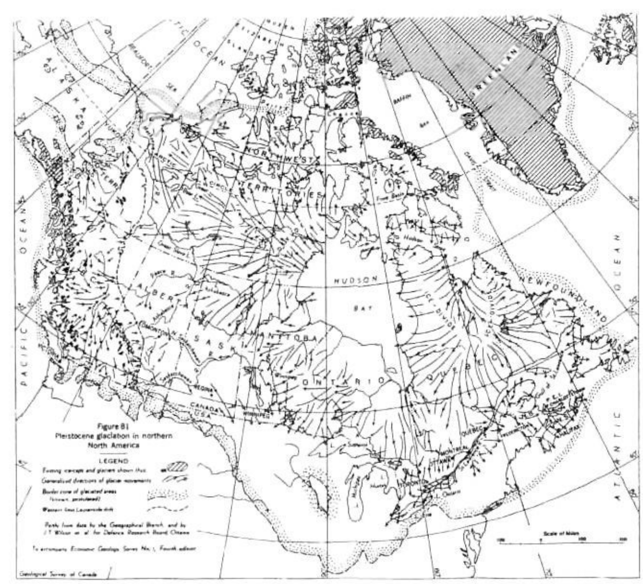


FIGURE 16. Pleistocene glaciation in northern North America (Prest, fig. 81, 1957).

La glaciation du Pléistocene dans le nord de l'Amérique du Nord (Prest, fig. 81, 1957).

1. Of the sixteen committee members, only Hugh Bostock, formerly with the Geological Survey of Canada, is alive and active. He participated on an INQUA '87 trip to his former haunts in Yukon Territory.

method of developing the contiguous ice masses on the Keewatin, Baffin and Québec-Labrador plateaux.

Craig and Fyles (1960) proposed an Ellesmere-Baffin Glacier Complex contiguous with the northeastern part of Laurentide Ice Sheet, and suggested only local Wisconsin ice caps on the western Queen Elizabeth Islands where a regional ice sheet had occurred earlier. It has since been shown that the Ellesmere-Devon Islands ice was quite separate from the Baffin Island ice which was a part of the Laurentide Ice Sheet. But the concept of an Ellesmere-Baffin glacier complex was later incorporated in the all-time glacier cover as depicted by Flint (1971) (Fig. 19).

Meanwhile Ives and Andrews (1963) presented a wealth of data on north-central Baffin Island, along with a "graphic and hypothetical interpretation" of the data. Their figures 19-21 reveal a Foxe-Baffin ice sheet centred over Foxe Basin at the last glacial maximum with the centre or ice divide shifting eastward onto Baffin Island during recession of the ice sheet and incursion of the sea into Foxe Basin. It is obvious from their figure 22 that the present-day Barnes Ice Cap is a remnant of their retreating ice sheet and hence is the last lowland remnant of the former vast Laurentide Ice Sheet. Only their figure 19 is reproduced herein (Fig. 17). Then Blake (1966) provided much detailed information on the glaciation and ice recession from southern Baffin Island.

In 1965 Mackay published the preliminary results of his experiments on simulating the flow of the Wisconsin ice sheet using an analogue field plotter. The results were quite encour-

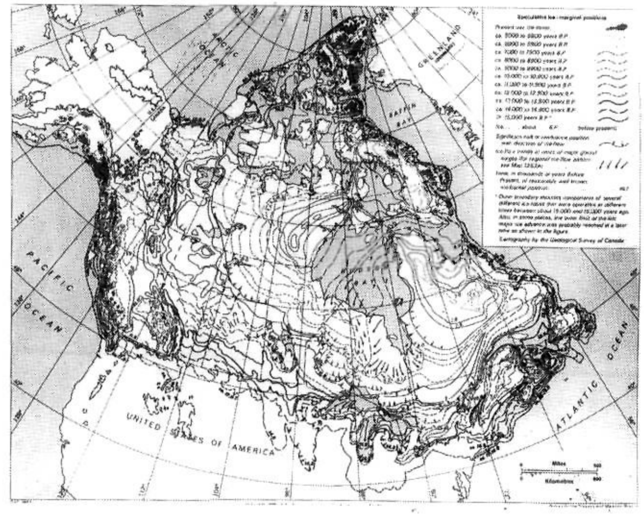


FIGURE 18. Stages in the deglaciation of Wisconsin ice [Prest, Fig. XII-15, 1967 (1970)].

Étapes de la déglaciation au Wisconsinien [Prest, fig. XII-15, 1967 (1970)].

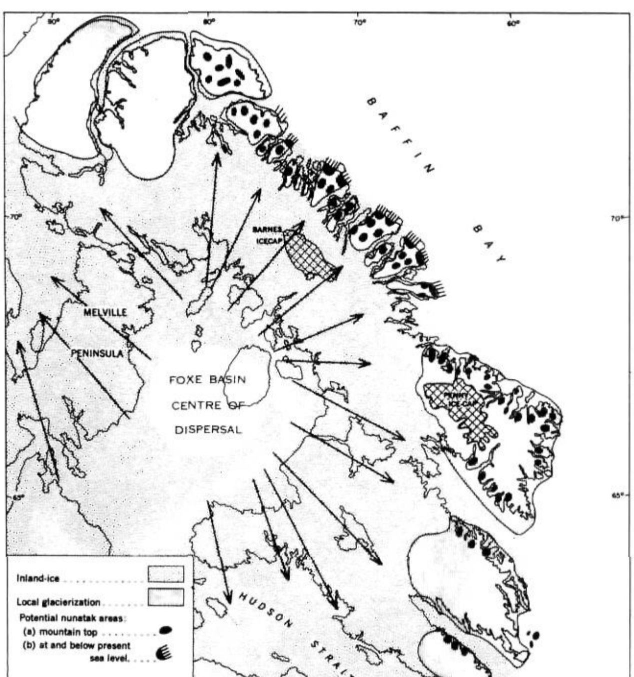


FIGURE 17. Representation of "... the estimated conditions of maximum glacierization..." (Ives and Andrews, Fig. 19, 1963).

Illustration de l'estimation de conditions d'englacement maximal (Ives et Andrews, fig. 19, 1963).

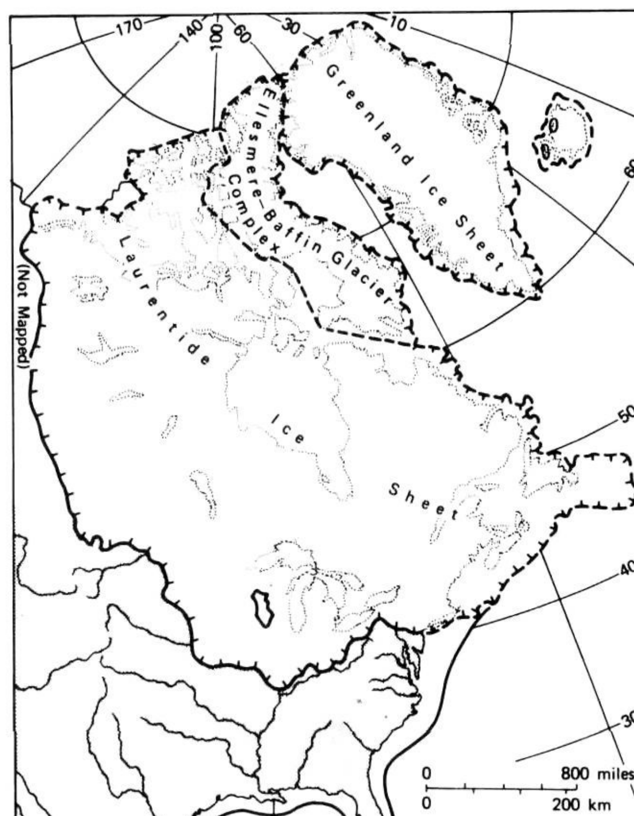


FIGURE 19. Sketch map showing extent and broad subdivision of glacial age glaciers regardless of age, east of the Cordillera (Flint, Fig. 18-5, p. 478, 1971).

Carte schématique montrant l'étendue et les limites des glaciers de l'âge glaciaire, indépendamment de leur âge, à l'est de la Cordillère (Flint, fig. 18-5, p. 478, 1971).

aging yet decades passed before computers were again employed to provide further information on the ice sheet.

In 1967 Prest produced a sketch map showing the North American ice sheet *in toto* and its pattern of ice retreat. This sketch (Fig. XII-15 in Prest, 1970) is entitled 'Stages in the deglaciation of Wisconsin Ice'. (Fig. 18). This was followed by a larger, ice-retreat map (Prest, 1969). In both maps the Laurentide ice was shown as retreating toward elongate ice-divide areas in Keewatin and on Baffin Island, and to a hook-shaped divide in Québec/Labrador. The Keewatin and Labrador ice masses for the first time were referred to as sectors of Laurentide Ice Sheet, but the ice masses in the Foxe-Baffin and Appalachian regions were each considered under the term 'Glacier complex' pending further definitive work.

Blake (1970) proposed a Late Wisconsinan *Innuitian Ice Sheet* situated over the entire Queen Elizabeth Islands (see p. 60-61). This concept was to account for the over-deepened channels between the western islands as noted by Pelletier (1962), Marlowe (1968) and Hattersley-Smith (1969), and, notably, on the location of the zone of greatest uplift over the main divide of the submerged and glacially modified drainage system as postulated by Fortier and Morley (1956). And Blake comments that the size of the fiords on northern Bathurst Island suggests that the island ice was part of a major ice sheet that covered all the adjacent islands and their intervening channels. The observations of Tozer (1956, p. 26-27); Tozer and Thorsteinsson (1964, p. 32-41, p. 200); Fyles (1965); and Hodgson (1989, in press), however, appear to indicate that the major ice cover of the western islands was of Laurentide origin. Fyles with the aid of a Piper Super Cub aircraft, with oversized landing wheels, made observations at some 250 localities on the western islands. He concluded, on the basis of scattered Shield erratics, that Laurentide ice had indeed overridden these Queen Elizabeth Islands during one or more 'older' glaciations whereas the last or Late Wisconsinan ice sheet had probably only impinged on the southern part of Melville island.

The extent of the last ice sheet in northeastern Ellesmere Island has been called into question by England (1976). He has suggested that the term Innuitian Ice Sheet for the Queen Elizabeth Islands ice cover be reserved for an older and more extensive ice sheet but this does not circumvent the presence of mainland erratics (from the south) on the western islands rather than erratics from the east. England suggested that the less extensive Late Wisconsinan ice sheet be termed the 'Franklin Glacier Complex'. A less extensive ice sheet, however, presents even greater problems in accounting for the magnitude of the Holocene isostatic uplift over the western islands and particularly over Bathurst Island as determined by Blake — which uplift is undoubtedly real. It is obvious that more glacial-geological evidence from the low western islands is needed before the uplift problem can be resolved. The evidence of tectonic adjustments during the Holocene, in the region to the south, as proposed by Dyke *et al.* (1989) may well point to a solution of the isostatic anomalies over the western Queen Elizabeth Islands. And in this same regard Tozer and Thorsteinsson (1964) stated "...the main period of uplift following the Tertiary planation involved vertical movement of individual islands. This was probably achieved by movement on gravity faults betwen the islands rather than by epeirogenic adjustment affecting the Archipelago as a whole".

Ives, Andrews, and Barry (University of Colorado) in 1975 published a most informative article on the growth and decay of the Laurentide Ice Sheet. They re-emphasized the concept of 'instantaneous glacierization', due to snowline lowering, as the most likely method of rapid and extensive ice-sheet growth, and their figure 1 clearly indicates the 'Laurentide Ice Sheet'. But in spite of thus developing an ice cover on the low-lying Keewatin region at the last glacial maximum, they appear to have favoured a single-domed ice sheet centred over Hudson Bay. Their figure 4 illustrates a late glacial breakup into separate Keewatin, Baffin, and Labradorean ice masses much as did Flint. And there have been other more recent models such as those of Hughes *et al.* (1977) and Mayewski *et al.* (1981) showing such a single-domed concept together with a resulting eastward ice flow across Québec, and by analogy, westward flow from the dome into and across District of Keewatin (Fig. 20). There is at this date, however, no field evidence of glacial transport from Hudson Bay or James Bay eastward into Québec but only west and southwest flow from central Québec as earlier reported by Low (1888). By 14,000 BP, however, they show dispersal domes in Keewatin and central Québec with a 'saddle' in Hudson Bay (Fig. 20b), such as was envisioned by Flint (1943).

In the case of the Keewatin region, W. W. Shilts and his GSC co-workers (Shilts *et al.*, 1979; Shilts, 1980, 1982, 1985; Shilts and Aylsworth, 1987) have shown conclusively that there was eastward transport towards Hudson Bay throughout the Late Wisconsinan and probably even earlier. And this surely supports Tyrrell's earlier deductions as to the southeast-shifting ice centres in Keewatin, and ice flow toward the Bay (Tyrrell, 1897, p. 175, and diagram 621). Shilts' (1982) account of the Quarternary evolution of the Hudson-James Bay region provides vital information on both changing concepts and drift dispersal, pertinent to this present brief account of the Laurentide region *in toto*. A paper by Dyke *et al.*, 1982 on the region north of the Keewatin centres of dispersal, lends support to these observations as it describes strong eastward flow from M'Clintock Channel toward Gulf of Boothia. Their figure 4 shows ice flow off the M'Clintock ridge, the eastward Keewatin flow of Shilts *et al.* (1979), and flow from a dome in southern Hudson Bay. Labrador ice is shown as flowing from the Labrador Ice Divide and as limited to the eastern side of Hudson Bay (Fig. 21). An updated small ice-flow trend map (Prest 1983, Fig. 1), and inserted in Prest (1984) together with a large map, both by the Geological Survey of Canada, provide a bird's-eye view of the ice-flow trends that must be accommodated in the development of ice-sheet models of the Laurentide Ice Sheet. The name Laurentide Ice Sheet is clearly shown on the above maps as indicated in (Fig. 22).

Ice sheet models based on the computer program developed and described by Reeh (1982) are of great interest. When this program was applied to Greenland it produced very acceptable results as regards known ice divides, saddles, ice streams and ice thickness. It has since been applied in Canada (Fisher *et al.*, 1985). According to these authors the Reeh program makes use "...of a very simple, ideal plastic ice rheology and

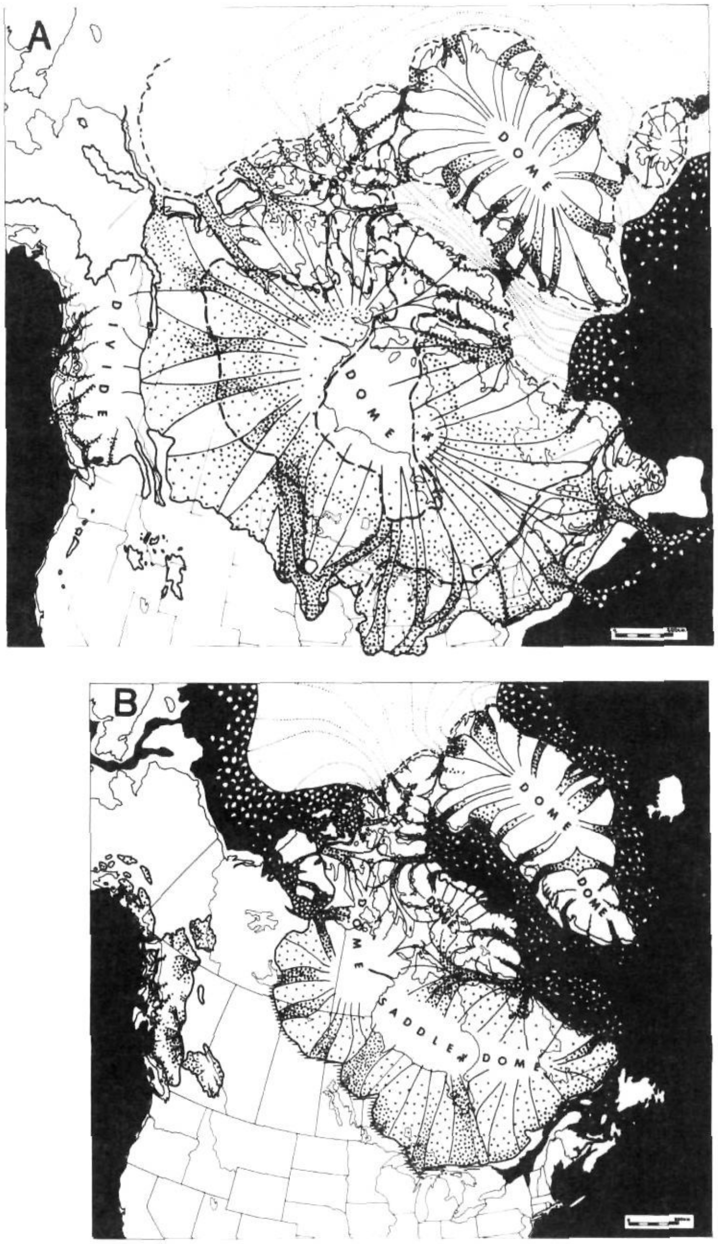


FIGURE 20. Glaciological reconstructions of the North American ice cover between 21,000 and 17,000 BP, and at 14,000 BP (Mayweski *et al.*, Figs. 2-4, 2-5, *in* Denton and Hughes, 1981).

Reconstitutions glaciologiques de la couverture glaciaire de l'Amérique du Nord entre 21 000 et 17 000 BP, et à 14 000 BP (Mayweski et al., fig. 2-4, 2-5, in *Denton et Hughes, 1981).*

FIGURE 21. Structure and dynamics of the Laurentide Ice Sheet during the Late Wisconsinan maximum (Dyke *et al.*, Fig. 4, 1982).

Structure et dynamique de l'Inlandsis laurentidien au maximum glaciaire du Wisconsinien supérieur (Dyke et al., *fig. 4, 1982).*

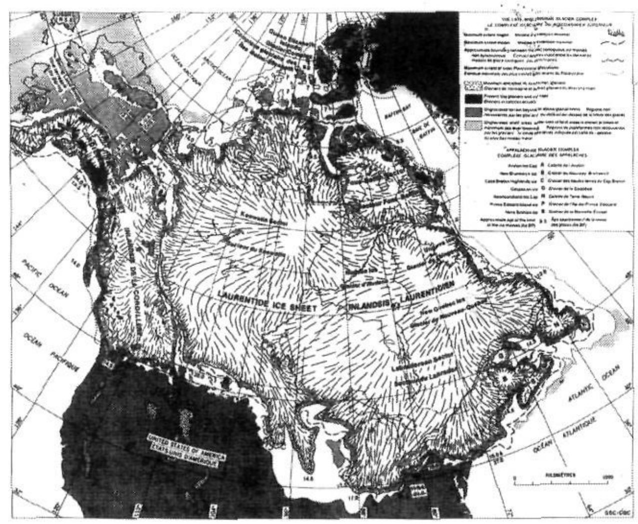


FIGURE 22. The Late Wisconsinan glacier complex (Prest, Fig. 1, 1983).

Le complexe glaciaire du Wisconsinien supérieur (Prest, fig., 1, 1983).

takes as input only the margins of the ice sheet, the present topography, and an assumed yield shear stress 'ro'. Flowline calculations begin at a point on the margin, and integration of the equation proceeds upslope using only the margin's shape, the underlying topography, and the yield stress — no assumptions are made in advance about ice divides, centres or streams; these fall objectively out of the calculations".

Using a normal shear stress (non-deformable beds) for the Shield and Hudson Bay but a low shear stress for the deformable beds of the Prairies and the Great Lakes basins, the program produced a model with a major elongate northwest/southeast-trending ridge in southwestern Hudson Bay connected to domes in Keewatin and in Québec, with many secondary divides throughout the continental region. Except for the northeastward ice flow indicated across the Ungava Peninsula, (Fig. 23a) the portrayal has many elements that accord well with known geological data. When the program was re-run employing a low yield stress for the Hudson basin [because of its Paleozoic limestone base], the major ice-divide system was shifted noticeably to the west, southwest and southeast of Hudson Bay. This portrayal is generally in some conflict with geological data in the south but it does provide a very acceptable picture for the Ungava Peninsula (Fig. 23b). It is quite obvious from these computer reconstructions that given a more detailed topographic grid, a more precise ice-sheet margin, and a better handle on the deformable bed/shear

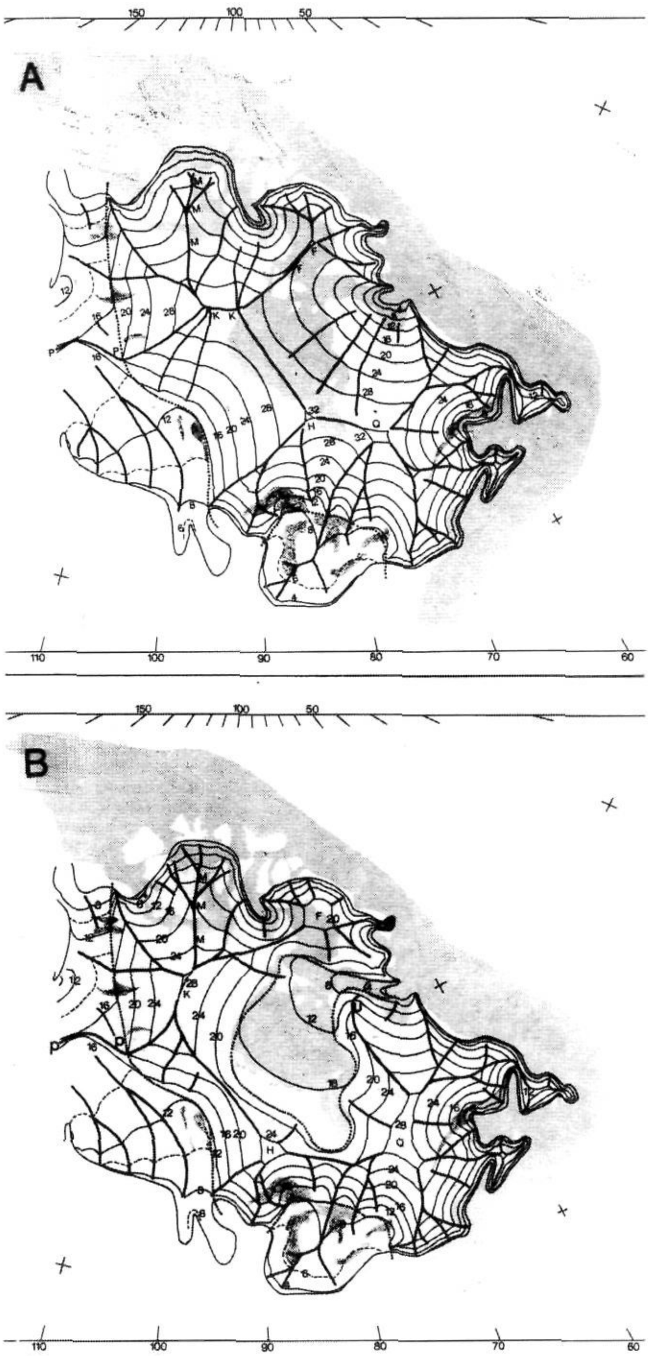


FIGURE 23. A. Computer reconstruction of the Laurentide Ice Sheet at 18 ka assuming a hard Hudson Bay and deformable Prairie and Great Lakes beds (Fisher *et al.*, Fig. 2, 1985). B. Computer reconstruction of the Laurentide Ice Sheet at 18 ka with a deformable Hudson Bay, Prairie and Great Lakes beds (Fisher *et al.*, Fig. 3, 1985).

A. Reconstitution par ordinateur de l'Inlandsis laurentidien vers 18 ka en supposant la présence d'un lit rigide dans la région de la baie d'Hudson et de lits non résistants dans les régions des Prairies et des Grands Lacs (Fisher et al., *fig. 2, 1985). B. Reconstitution par ordinateur de l'Inlandsis laurentidien vers 18 ka en supposant la présence de lits non résistants dans les régions de la baie d'Hudson, des Prairies et des Grands Lacs (Fisher* et al., *fig. 3, 1985).*

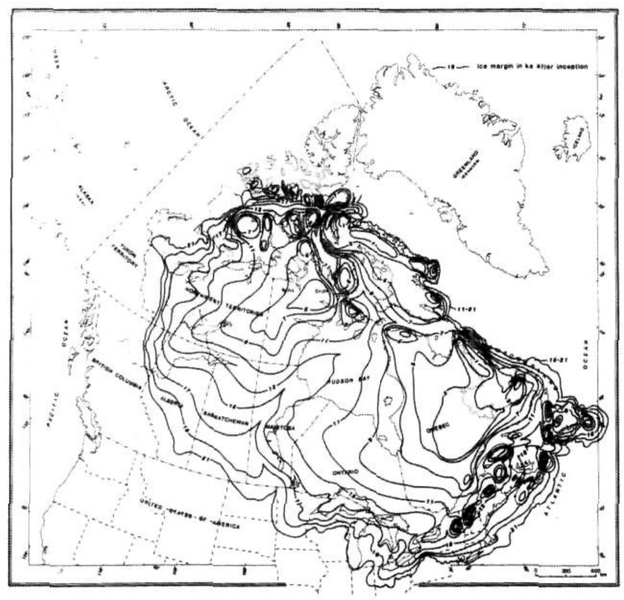


FIGURE 24. Hypothetical growth of the Laurentide Ice Sheet following the last interglaciation (Vincent and Prest, Fig. 4, 1987).

Modèle hypothétique montrant la croissance de l'Inlandsis laurentidien après le dernier interglaciaire (Vincent et Prest, fig. 4 1987).

stress information, that an overall portrayal in close agreement with known geological data might well result.

In the case of the Early Wisconsinan, Vincent and Prest (1987, Fig. 5) have produced a growth model combining the concepts of some other scientists and also utilizing the evidence of early ice-flow indicators of west to northwest ice flow across northern Ontario (Fig. 24). The model assumes that under the influence of a lowering snowline the Labrador Sector ice would expand westward across northern Ontario somewhat in advance of the infilling of the Hudson basin. The model assumes that the Labrador Ice encountered Keewatin ice in northeastern Manitoba, as it did in the Late Wisconsinan, but the evidence from the dispersal of certain indicator erratics suggests that Early Wisconsinan Labrador Sector ice may have gone much farther to the west before encountering the Keewatin ice — as it certainly did at some earlier time or times [see Dispersal of Erratics].

A geologically acceptable portrayal of the continental ice cover in the Late Wisconsinan has been published by Dyke and Prest (1987). They present a revised picture of the retreat of the Laurentide Ice Sheet and its correlative ice masses (Map 1702A) and a series of paleogeographic maps showing the Late Wisconsinan and Holocene retreat of the ice between 18 and 5 ka (Map 1703A). The major ice divide of the Laurentide Ice Sheet is referred to as the Trans-Laurentide Ice Divide; it has major domes in west-central Québec, east of Great Slave Lake and in Foxe Basin with saddles southwest of Churchill, Manitoba, and off the northwest end of Southampton Island. The major secondary divides are also shown and named. The series of paleogeographic maps traces the shifting of the divides and domes through time with their accompanying correlative geographic features.

The different parts of the Laurentide Ice Sheet during the Late Wisconsinan maximum at *ca.* 18 ± 4 ka by Occhietti (1987) provides a clear picture of the recent concepts of several authors (Fig. 25).

The chronology of our changing concepts from 1845 to the present is presented in Table I.

HUDSON BASIN ICE

From the foregoing sketches and models it is obvious that the development of a major ice mass in the Hudson basin, and its dispersal pattern, is a matter of paramount concern. If the ice was free to drain through Hudson Strait how could a major dome or ridge develop within the Hudson basin? Flint (1943) was the first to suggest blockage of the Strait. He related that it was a necessary step in the continued northwestward growth of his Laurentide ice sheet. The growth of ice by the 'instantaneous glacierization' concept would not negate this need. Andrews and Mahaffy (1976) in one of their mathematically-derived models of ice-sheet growth, though not their preferred model, also indicated ice from the Ungava Peninsula and Baffin islands plugging the western end of Hudson Strait after 5000 years of growth. And their other models of growth after 5000 and 10 000 years do not preclude blockage of the Strait during the glacierization process. Prest (1984) suggested development of an ice dome in Ungava Bay and eastern Hudson Strait. Such a dome would account for the distribution of Paleozoic erratics on southeastern Baffin Island (Muller, 1980). It would also serve as the ice plug in Ungava Bay and the adjoining lower George River basin in northern Québec. Some such ice mass is necessary for the formation of glacial lakes Naskaupi and McLean in the George River basin during recession of the ice from northeastern Québec-Labrador. Recently R.A. Klassen, GSC (pers. comm., 1988) has provided an alternative model as to the timing of the ice plug; this is in better accord with the regional ice-flow pattern in northern Québec, as well as the required distribution of erratics from the Labrador Trough. Klassen's model, however, invokes a Late Wisconsinan ice mass, though not a dome, in Ungava Bay. From the above-suggested blockages and general character of Hudson Strait, it may be that the strait only served as an outlet for interior ice during recessional times of high sea level — at which times an ice shelf probably extended over the outlet ridge into the Labrador Sea.

Given restricted ice flow to the north and east out of the Hudson Basin during protracted glacierization, coupled with strong Keewatin and Labrador ice flow into the basin, there would be an early build-up of ice in the topographically confined southern part of the region. Also the Labrador ice may have developed over northern Ontario prior to infilling of Hudson Bay proper thus necessitating even thicker ice in Hudson basin prior to the development of the regional southwest flow over northern Ontario (see Glacial Map of Canada, Prest *et al.*, 1968). The presumed growth of Early Wisconsinan ice as above mentioned is illustrated in Vincent and Prest (1987). Northwest and west-trending striae in northern Ontario, that pre-date the Late Wisconsinan southwest flow, have been observed over a wide area (Prest, 1963; L.H. Thorleifson and P.H. Wyatt, GSC pers.

FIGURE 25. The different parts of the Laurentide Ice Sheet during the Late Wisconsinan maximum *ca.* 18 ± 4 ka. (Occhietti, Fig. 1, 1987).

Les différentes parties de l'Inlandsis laurentidien pendant le maximum glaciaire du Wisconsinien supérieur, vers 18 ± 4 ka (Occhietti, fig. 1, 1987).

comm., 1988). Some of these striae may have been seen by Tyrrell (1913a) and embodied in his Patrician ice centre concept. [This older flow is not to be confused with the evidence of Late Wisconsinan westward flow induced by calving into glacial Lake Agassiz nor with the late, Miminiska ice advance (Prest, 1963).] The build-up of ice in southern Hudson basin must have attained a great thickness to bring about the regional southwest and south flow that extended to the presumed Early and Late Wisconsinan terminal zones in the northern United States. Thick as this ice may have been, however, it did not constitute an independent Wisconsinan dispersal dome or ridge but was merely a major remnant of the active west and southwest flowing Labrador Sector ice. It represents a part of the Trans-Laurentide Ice Divide of Dyke and Prest (1987). At the Late Wisconsinan maximum the 'divide' was probably in the lowland of northern Ontario, but as the Late Wisconsinan Labrador ice receded and the southern part of the ice retreated northward in northern Ontario, the Trans-Laurentide Ice Divide migrated northward from the lowland into Hudson Bay proper (Dyke and Prest, 1987). When the receding ice front was north of the height-of-land the ice calved southward into glacial Lake Ojibway. The Cochrane surges took place into the lowering phases of this lake from the recessional loci of the Trans-Laurentide Ice Divide in southern Hudson Bay. Little is known as to correlative events in the ice sheet in the northern part of Hudson Bay prior to the full incursion of the Tyrrell Sea.

DISPERSAL OF ERRATICS

The dispersion of a variety of erratics in various parts of the Laurentide region (Prest and Nielsen, 1987) is a direct means of identifying former ice-flow trends. Two types of erratics are

TABLE I

Evolution of terminology and concepts of the Quaternary North American ice masses, with emphasis on the Canadian scene

Author, date	Terms used, concepts introduced, notations, illustrations
Logan, 1845 (1847)	Glaciation in Temiscamang Valley [Temiskaming-Ottawa valley, Ontario]
Logan, 1863	Records glacial striations, grooves and erratics of the drift period in Canada, 1842-62
Bell, R. fieldwork 1865-77	Recorded trend of ice flow features across diverse parts of central Canada; did not refer to any specific glacier mass; first coloured map of Surficial deposits between Lake Superior and the Gaspé, 1865 (1867)
Dawson, 1872	First Glacial Map of Canada [now only eastern Canada]; [believed striae due to floating ice and Arctic currents] (Fig. 1)
Hitchcock, 1878	Map of Eastern North America (Fig. 2a)
Bell, R. fieldwork 1878-79	Recognized boulders on Manitoba side Hudson Bay as derived from east side of bay; recorded striae along Nelson and Churchill rivers indicative of west and southwest-flowing glacier ice
Davis, 1881	First sketch map of North American glacier cover (Fig. 26)
Chalmers, R. fieldwork 1883-95	Recognized multiple stages of ice flow over New Brunswick
Bell, 1886	Confirmed westward ice flow from east of Hudson Bay and dispersal Proterozoic rocks across Northern Ontario and Manitoba
Low, 1888	Continental glacier flowed from region east of Hudson Bay
Tyrrell, J.B., fieldwork 1887-90	Recorded striations in (what is now) west-central Canada; first reference to ice flow from (what is now) Keewatin District westward through basin Lake Athabasca and southward across the Plains
Dawson, 1891	Cordilleran glacier and Laurentide glacier named
Chamberlin, 1894	'Ideal map of North America during the Ice Age' — a circular pattern sketch showing Keewatin and Labradorean dispersal centres (Fig. 3)
Low, 1896	Ice flow from a gathering ground east of Hudson Bay
Upham, 1896	Map of drift-bearing area of North America with Cordilleran and Laurentide ice sheets named (Fig. 4)
Tyrrell, 1896, 1897	Sketch of shifting centres of Keewatin glacier; applied name Labradorean glacier to Low's ice mass east of Hudson Bay (Fig. 5)
Tyrrell, 1898	Sketches showing sequential growth of Keewatin and Labradorean ice sheets from west to east (Fig. 6)
Low, 1902	Refers to northwest-shifting centres of the Labradorean ice sheet [later figured by MacLean]
Chamberlin, 1907	(a) A concentric-pattern sketch with labelled centres of dispersal; (b) first comprehensive sketch of ice-flow trend-lines from dispersal areas (Fig. 7)
Chamberlin, 1913	First coloured, large-scale glacial map of North America (a Rand McNally map) (Fig. 8)
Tyrrell, 1913	A 'circle' diagram of the Patrician glacier (Fig. 9)
Martin, L., 1914, 1916	Sketch map of generalized ice flow from indicated dispersal areas; separate Arctic islands ice caps (Fig. 10)
Coleman, 1922	A concentric-pattern sketch of ice dispersal areas numbered from west to east (Fig. 11)
Coleman, 1926	Stressed Labradorean & Keewatin ice sheets as separate entities
Alden, 1924	Concentric pattern map with the labelled ice centres (Fig. 12)
Martin, 1932, 1935	Modified sketch of his earlier generalized ice flow lines (Fig. 13)
Flint, 1943	Westward growth of the Laurentide Ice Sheet
MacLean, 1944	Sketch showing areal coverage Keewatin and Labradorean ice sheets; northwest-shifting Labradorean dispersal centres (after Low) (Fig. 14)
Glacial Map of North America 1945, 1949	Geological Society of America, Washington
Wickenden, 1947	Sketch map of much generalized ice-flow trend-lines (Fig. 15)
Prest, 1957	Pleistocene glaciation in northern North America: directions of glacier flow, western limit Laurentide ice sheet, Keewatin and Labradorean ice-divides (Fig. 16)
Ives, 1957	Introduced concept instantaneous glacierization
Sim, 1960	Foxe-Baffin dispersal centre
Mackay, 1960	Glacier flow and analogue simulation
Ives & Andrews, 1963	Foxe Basin dispersal centre (Fig. 17)
Prest, 1967	Figure showing stages in the deglaciation of Wisconsin ice (speculative ice-marginal positions) (Fig. 18)
Flint, 1971	Sketch map showing extent and broad sub-division of glacial-age glaciers, regardless of age, east of the Cordillera (Fig. 19)
Mayewski *et al.*, 1981	Sketch map of the Laurentide Hudson domal concept at a glacial maximum, followed by a dome-saddle-dome concept during deglaciation (Fig. 20)
Dyke *et al.*, 1982	Structure and dynamics of Laurentide Ice Sheet during the Wisconsinan maximum; five centres and divides — M'Clintock, Foxe, Labrador, Hudson, Caribou (Fig. 21)
Prest, 1983, 1984	The Late Wisconsinan glacier complexe: Le complexe glaciaire du Wisconsinien supérieur (Fig. 22)
Fisher *et al.*, 1985	Computer reconstructions of Laurentide Ice Sheet (Fig. 23)
Vincent & Prest, 1987	Hypothetical growth model Early Wisconsinan Laurentide Ice Sheet (Fig. 24)
Occhietti, 1987	Laurentide Ice Sheet during the Late Wisconsinan maximum (Fig. 25)
Dyke & Prest, 1987	Late Wisconsinan and Holocene history of Laurentide Ice Sheet; Baffin, Labrador, Keewatin sectors; Trans-Laurentide ice divide, several named secondary divides

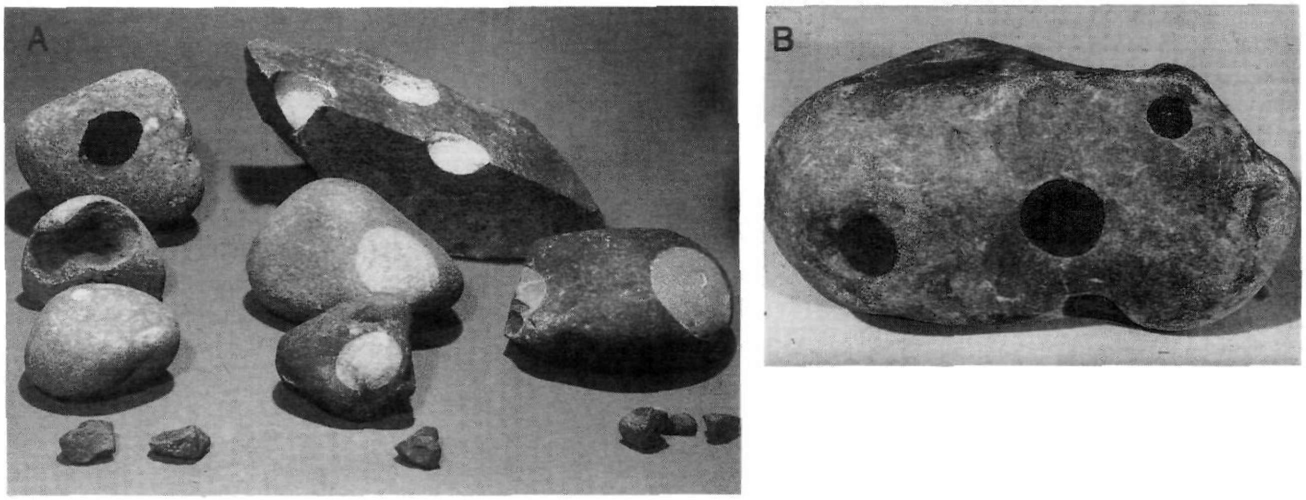


FIGURE 26. A. Representative omars from northern Ontario; oolitic jasper pebbles in foreground. B. 22 cm long omar cobble from Red Lake, northwestern Ontario.

A. Grauwackes de la Formation d'Omarolluk représentatifs, recueillis dans nord de l'Ontario; au premier plan, jaspe oolithique. B. caillou de grauwacke de 22 cm de longueur de Red Lake, au nord-ouest de l'Ontario.

given fuller discussion in this paper because they are pertinent to our ever-changing concepts of ice-sheet growth. I deal specifically with the dispersal of two types of erratics from the Proterozoic-age Belcher Islands Fold Belt Group in southeastern Hudson Bay. These are an oolitic jasper, and a greywacke with concretionary 'eyes' or irregular patches (Fig. 26). The oolitic jasper is a common constituent of many bands of iron formation that occur on the Belcher Islands. The greywacke with concretions is one of many wackes that outcrop on parts of the main group of islands and on many of the islands and shoals adjoining that group. The greywacke with concretions constitutes an upper part of the Omarolluk Formation, itself an upper part of the Belcher Group (Jackson, 1960). The Omarolluk and the overlying Loaf Formation are believed to occupy a major part of the area between the Belcher Islands and the Québec shore (Jackson, *op. cit.*). In mapping the distribution of these two erratics — the greywacke with concretions, and the oolitic jasper — it was considered convenient to simplify their names; thus the name 'omars' was coined and applied to erratics of greywacke with concretions or 'eyes' from the Omarolluk Formation, and 'jaspers' for the oolitic jasper from the Belcher Islands iron formations. These names are now in common usage from Ontario to the Foothills of Alberta. These two erratics are commonly found together. The omars occur as pebble to boulder-size erratics; the jaspers are mainly granule to pebble size. The generally rounded shapes of many omars, whether from gravels or tills, suggests that they were in part derived from pre-existing littoral or fluvial deposits.

Though Proterozoic in age and much folded, the Belcher Islands Fold Group rocks are little metamorphorsed. Thus oolitic jaspers found in glacial deposits overlying the Paleozoic strata of the Hudson Lowlands, or on the adjacent Archean terrain, may be safely assigned to this Proterozoic source because oolites are not apt to be preserved in the more-metamorphosed Archean iron formations. The strata of the Omarolluk Formation are especially noteworthy in their low grade of metamorphism; they have undergone remarkably little change of grain shape or texture. Low (1903) explained this phenomenon as the result of relatively shallow crustal thrusting and faulting, much as shore ice is now thrust layer on layer by wind and tide in that same region. The development of several types of concretions within the turbidite facies of the Omarolluk Formation is dealt with in reports by McEwan (1978) and Ricketts (1981). The latter also deals at length with the varied facies of the Omarolluk Formation and the overlying, more arkosic, Loaf Formation.

The Proterozoic greywacke erratics are distinguishable from Archean greywacke erratics by their shapes and low grade of metamorphism both in the field and in mineral fractions under a binocular microscope (C.Kaszycki, GSC, pers. comm.). But the name 'omar' does not apply to the Proterozoic greywacke (feldspathic greywacke) which does not display the concretions. The name 'greystone' was applied by Robert Bell more than a hundred years ago for the grey erratics from the northeast occurring in and on the drift overlying the Paleozoic lowlands west and southwest of James Bay and Hudson Bay (Bell, 1877, 1879b, 1886). He also observed greywacke with "eyes up to the size of cricket balls" (1886, p. 36G) in the drift overlying the Paleozoic strata and in lessening amounts westward over the Archean terrain. He reported the source of such rocks as from Long Island at the northeast end of James Bay. [But as the Omarolluk Formation is not presently known to occur on Long Island, it may be that he was misled by a profusion of erratics along the islands north shore, for the Omarolluk Formation lies only a short distance offshore (G.D. Jackson, GSC pers. comm.).] Bell also noted oolitic jasper as erratics in the drift on and beyond the Paleozoic strata west of James Bay. It is interesting also that Tyrrell (when working for the Ontario government) noted greywacke with calcareous white spots, that commonly weather to a rusty brown, from the mouth of the Nelson River in Manitoba east to the mouth of Severn River in northwest Ontario, and up that river to its headwaters but surprisingly, he was unaware of their source area (1913, p. 199). L.H. Thorleifson and P.H. Wyatt (GSC, pers. comm., 1988) have recently confirmed their occurrence along the Severn River, as well as the northwest-trending glacial striations as earlier reported by Tyrrell. Thus present day workers are but expanding on the observations and deductions of Robert Bell and Joseph Tyrrell, whose important data have been too long overlooked. The presently known distribution of the Belcher Islands erratics is shown in Figure 27.

The distribution of omars and jaspers in Central and Western Canada has been briefly dealt with in an earlier paper (Prest and Nielsen, 1987). Further studies have enlarged the areal coverage of omars and jaspers in Saskatchewan and provided a much more detailed picture of their distribution in northern Ontario.

The scattered occurrences of omars and jaspers across Saskatchewan and into Alberta, in the region of south-flowing Keewatin ice, assuredly suggests their earlier emplacement, by older Labrador Sector ice somewhere north of their present sitings. [There are no known occurrences of relatively unmetamorphosed Proterozoic rocks in northern Saskatchewan. The Proterozoic belt in East Arm, Great Slave Lake, NWT., includes grey fine-grained sediments, with concretions, but these are argilite not greywacke (P.F. Hoffman GSC, 1968, and pers. comm., 1988) and also the source area of the oolitic jasper there is limited.] The evidence at hand impels us to again con-

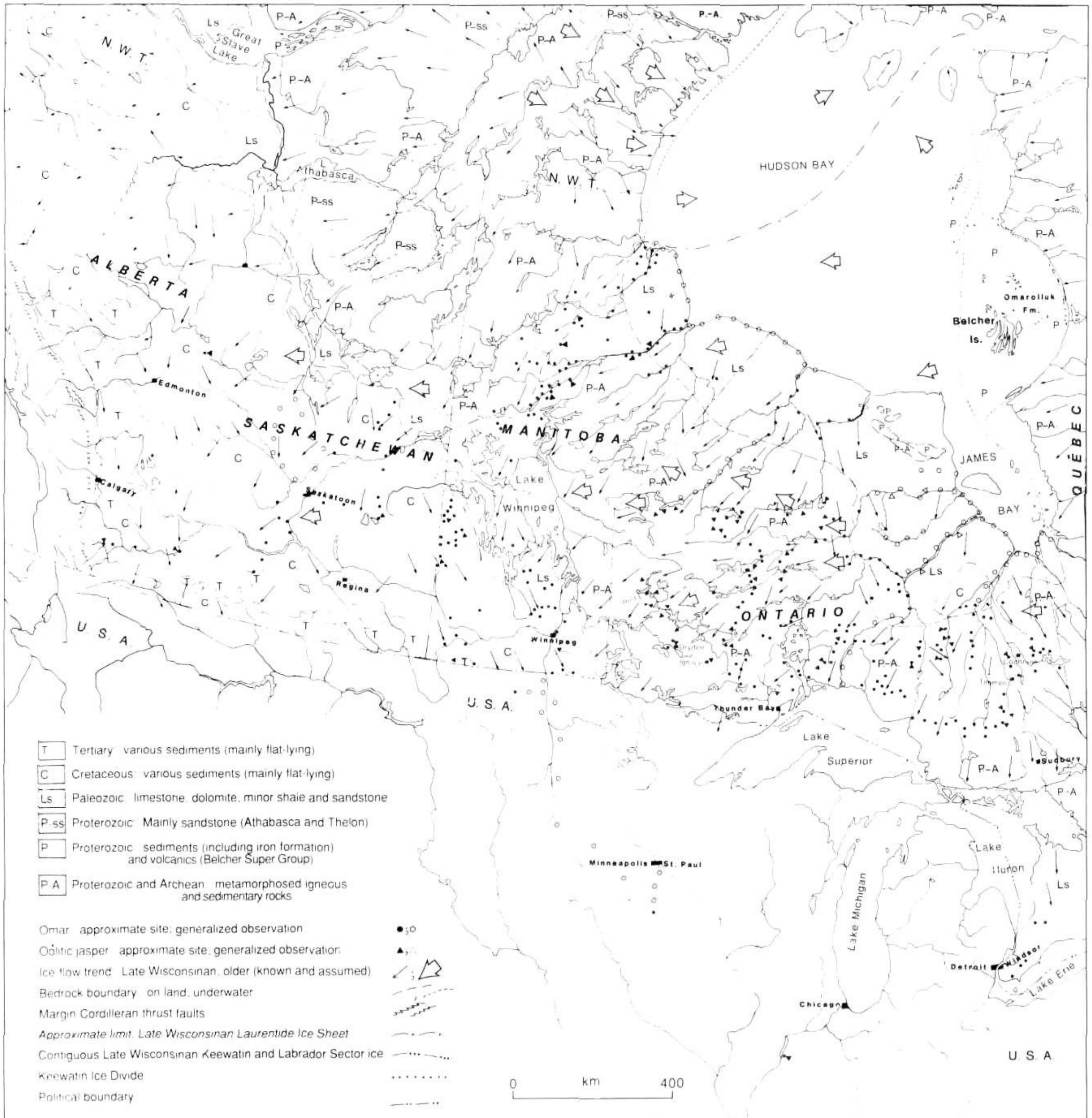


FIGURE 27. Distribution of omars and oolitic jaspers from the Belcher Islands region.

Répartition des grauwackes et du jaspe oolithique en provenance de la région de l'archipel de Belcher.

sider the westward growth and advance of Labrador Sector ice as envisioned by Flint (1943), in regard to the Wisconsin glaciation. But there is no evidence of this same westward growth in Keewatin District, NWT, where the ice flowed eastward into Hudson Bay probably throughout the Wisconsinan Stage (Shilts, 1980). Thus it would appear that Labrador ice, during one or more glaciations, expanded and flowed westward across the Prairies and the bordering Shield area to the north, but was restricted by the growth of Keewatin Sector ice farther north. At the Late Wisconsinian maximum, however, the Keewatin ice dominated over the Prairies and extended far southward into the United States. It remains to determine the northern limit of omar and jasper erratics in Saskatchewan and Alberta. They are now known to occur north to a point 160 km NNE of Prince Albert, Saskatchewan (see Fig. 28).

The overall distribution of omars and jaspers in Manitoba is well known due to the observations of E. Nielsen of the Mineral Resources Division, Manitoba Department of Energy and Mines. He has recorded their common occurrence along the Nelson River and along the lower part of the Churchill River, thus confirming the earlier report by Tyrrell (1913b). Nielsen has also noted their presence within older tills along these rivers, hence more than one invasion by Labrador Sector ice must be envisaged. Nielsen has noted a sharp decrease in the abundance of surface omars to the northwest more or less away from the zone of confluence between Labrador and Keewatin Sector ice (see Glacial Map of Canada, Prest *et al.*, 1968). But Kaszycki and DiLabio (1986) have noted omars on and south of the South Seal River in an area previously believed glaciated only by southward Keewatin ice flow. Also their detailed drift dispersal studies clearly indicate transport of both Paleozoic carbonates and Proterozoic greywacke westward as far as Granville Lake on the Churchill River. Shilts (1980) reports that neither 'greystones', omars, jaspers nor carbonates occur in the drift north of the Seal River.

Nielsen reports that omars are rather common north of Lake Winnipeg and to the southwest along the Manitoba escarpment but then decrease in number both southward and westward. Though sparse he has recorded their presence in the Interlake District and south to the International Boundary as well as in extreme southwestern Manitoba. Upham (1895, p. 131) noted the greywacke, with its round spots, in North Dakota and in Minnesota. All the erratics in southern Manitoba and USA are clearly within the region glaciated by Late Wisconsinan, Keewatin Sector ice.

The more detailed omar and jasper investigations in northern Ontario have confirmed their abundance over a variably broad zone of Archean terrain, with decreasing numbers to the south and southwest. They do not apear to be present beyond a line extending from Lake Abitibi in the east, southwest to Michipicoten on Lake Superior, northwestward close to that shore as far as Nipigon, where there is a small jog to the southwest, and then northwest again to Dryden, Lac Seul, and Red Lake (Fig. 29). On the other hand omars have been recorded by Ed Sado (Ontario Geological Survey) near the south end of Lake Huron and the west end of Lake Erie. Both omars and jaspers were noted southwest of Lake Michigan by Thorleifson and Prest (AMQUA field excursion, 1987). These distant southern and southwestern occurrences, far beyond the suggested 'limit' in northern Ontario, may well represent entrainment from older deposits. Alternatively they were carried high in the expanding ice sheet to the Wisconsinan terminal zone. It is suggested that the presumed 'limit' of omars and jaspers in northern Ontario represents the maximum dispersal, directly from the Belcher Islands region, by the Late Wisconsinan basal ice. Alternatively, this phenomenon relates to the 'activity limit' between warm-based Hudson Basin ice and cold-based ice on the upland south of the basin, somewhat as envisioned by Lagerlund (1987) for southeastern Sweden and its adjoining islands. His ice sheet growth and marginal dome formation is also pertinent to our changing concepts as regards the growth of the Labradorean Ice Sheet.

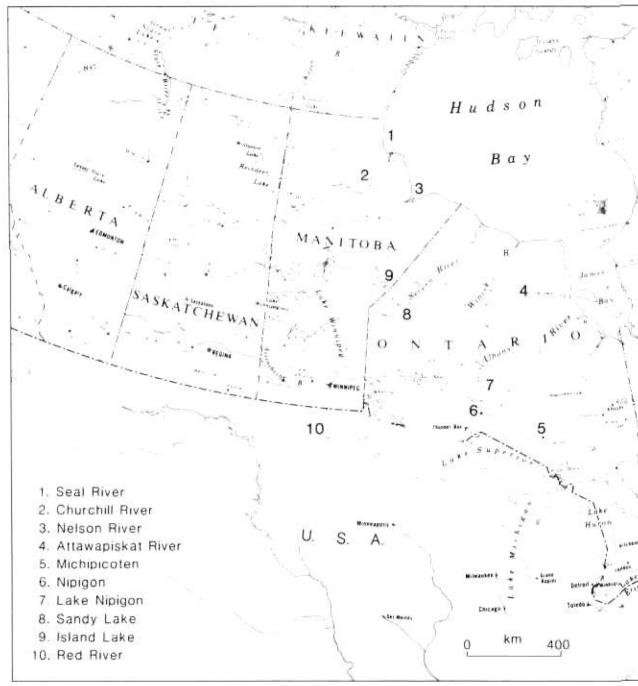


FIGURE 28. Location map (rivers, lakes and place names referred to in Dispersal of Erratics).

Carte de localisation (toponymes utilisés dans la section «Dispersal of Erratics»).

Caution is required in regard to the omars in Minnesota (Upham, 1895) for Proterozoic greywacke with concretions outcrops in northern Minnesota (Morey and Ojakangas, 1970). Some or all of these erratics may have been picked up locally in Minnesota by Labrador Sector ice and then redistributed by the Late Wisconsinan Keewatin ice, as must be the case for Belcher Islands erratics across the Canadian Prairies.

CONCLUSIONS

Early sketch maps of the North American ice cover emphasized the extent of ice rather than ice-flow patterns (Davis, 1881; Upham, 1895). The concept of two major regions of ice sheet dispersal was, however, clearly indicated by Chamberlin (1894), and this concept was accepted by scientists for some five decades. Flint (1943) introduced the concept of westward growth and flow of the ice from the Baffin and Labrador regions, followed by development of a dome in Hudson Bay. The

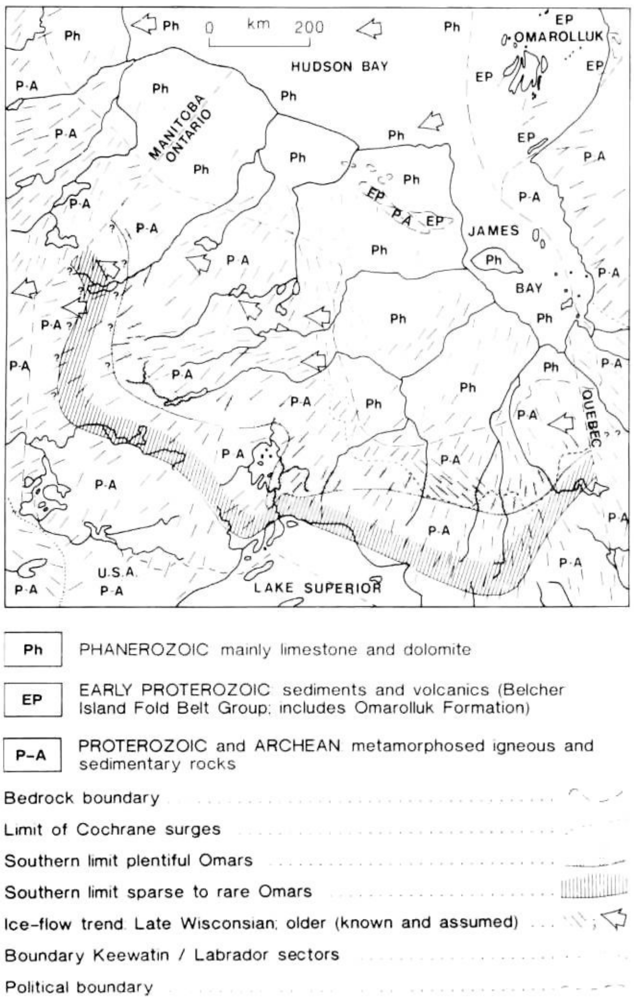


FIGURE 29. Limits of omars in northern Ontario.

Limites de dispersion des grauwackes dans le nord de l'Ontario.

Hudson dome concept persisted for several decades though it was not until Hughes *et al.* (1977) and Mayewski *et al.* (1981) that sketch maps of such a dome, and dispersal from it, were portrayed. It was already evident, however, that the single dome concept was not supported by geological evidence. And recent dispersal studies have proven the long-continued transport by Labrador Sector ice from Québec, west and southwest across Hudson Bay, as well as transport by Keewatin ice, north of Churchill, eastward into the bay. There is no geological evidence of transport eastward anywhere into Québec, nor westward into Keewatin District.

Geological investigations in the Hudson Bay Lowland of northern Manitoba and Ontario have shown that greywacke with calcareous concretions (omars) occur in both Wisconsinan and pre-Wisconsinan deposits. These erratics, along with oolitic jaspers, have clearly been derived from the Belcher Islands region by the flow of Labrador Sector ice. This indicates that Labrador Sector ice crossed the bay on two or more occasions. The indicated 'limits' of abundant and sparse omars in northern Ontario (Fig. 29) may indicate the transport limits of Late Wisconsinan basal ice. The far-distant southern occurrences may represent transport 'high in the ice', or else entrainment from older deposits. Alternatively the far distant occurrences may support the concept of peripheral growth of Labrador Sector ice as envisaged by Demorest (1943) and Flint (1943).

The omars and jaspers from the Prairie region pose a somewhat different problem in tracing ice-flow patterns. Though they are mainly in or on Late Wisconsinan deposits, they are also known to occur in older tills. But they all occur within the region of southward-flowing Late Wisconsinan Keewatin Sector ice. The writer and E. Neilsen believe that Labrador Sector ice invaded the Prairies Region prior to the full development of Late Wisconsinan Keewatin Sector ice and that the omars and jaspers have been re-deposited. [The necessary growth of Labrador ice in advance of the Keewatin ice over the Prairies was not indicated on the Early Wisconsinan growth portrayal (Fig. 24).] It cannot be stated emphatically, however, that the omar and jasper occurrences across the Prairies do not represent, or at least include, direct dispersal by Keewatin ice from a number of minor, but as yet unknown, Proterozoic sources in the north. The occurrence of oolitic jasper, though not omars, in East Arm, Great Slave Lake provides food-for-thought in this regard. Similarly it should be noted that Proterozoic wackes, including those with calcareous concretions occur at the western end of Lake Superior (Morey and Ojakangas, 1970). Thus there is a source in that region (Thomson Formation) that may well account for the distribution of omar-type erratics in Minnesota and perhaps in parts of North Dakota as were observed by Upham (1895, p. 131), but again early westward Labrador Sector ice flow followed by southward Keewatin flow must be envisaged. In summary it is evident that our concepts of ice sheet growth and the dispersal of erratics is in a state of flux though multiple centres of outflow is an established fact.

ACKNOWLEDGEMENTS

The writer is much indebted to J. Phil. Schafer of the United States Geological Survey for tracking-down and clarifying information on some of the early American scientists and their publications. He also acknowledges the encouragement of other Quarternary colleagues to publish this modified Plenary Session address of the INQUA/87 Congress in Ottawa. He is grateful to Phil. Forstal, the Map Librarian of Rand McNally, and to the American Geographical Society for arranging and supplying him with a reduced photo-copy of T.C. Chamberlin's 1913 coloured map.

Sincere thanks are extended to Erik Nielsen of Manitoba Mineral Resources Division without whose observations across the Prairie Provinces our knowledge of the distribution of Belcher Islands erratics would be most incomplete. He is also indebted to Brian Schreiner of Saskatchewan Research Council for services and assistance in regard to these erratics in Saskatchewan.

The writer is grateful for the field support of the Ontario Geological Survey in 1986, including the assistance of John Easton, when we were specifically searching for Belcher Islands erratics in northern Ontario. And Edward Sado of their Engineering and Terrain Geology Section was most helpful and cooperative in regard to the study of the Belcher Islands erratics over several years.

The writer acknowledges the constructive review of a preliminary draft of this paper by R.J. Fulton, and the later critical review and proferred suggestions of A.S. Dyke, both of the Geological Survey. Helpful comments and suggestions by D.R. Sharpe and L.H. Thorleifson have improved the manuscript. He also wishes to acknowledge the facilities that have been provided and the encouragement given over many years by the Geological Survey of Canada. The typing services of Ms. J. Barr and Ms. M. Slegr, and the assistance of Ms. L. Maurice in preparing illustrative material, are gratefully acknowledged.

REFERENCES

Alden, W. C., 1924. Physical features of central Massachusetts, Map showing area covered by the great ice sheets in North America at their maximum extension and the centers of ice accumulation, Fig. 5. *In* Contributions to the geography of the United States 1923-24. United States Geological Survey Bulletin 760, 1924.

Andrews, J. T. and Mahaffy, M. A. W., 1976. Growth rate of the Laurentide Ice Sheet and sea level lowering (with emphasis on the 115,000 B.P. sea level low). Quaternary Research, 6: 167-183.

Atwood, W. W., 1940. The physiographic provinces of North America. Blaisdale, Boston [see Fig. 74, p. 156].

Bell, R., 1865. Surficial deposits between Lake Superior and the Gaspé. Atlas to Geology of Canada, 1863 (1867).

——— 1866. [Report on the Manitoulin Islands; see Superficial geology, p. 177]. Geological Survey of Canada, Report of Progress from *1863 to 1866*, p. 165-179 (1866).

——— 1870. [Report on country off northwestern side Lake Superior; see Surface geology, p. 351-357]. Geological Survey of Canada, Report of Progress for *1866-1869* (1870).

——— 1871. Report on the country north of Lake Superior between the Nipigon and Michipicoten rivers [see Surface geology, p. 349-351]. Geological Survey of Canada, Report of Progress for *1870-71*, p. 322-351 (1872).

——— 1872. Report on the country between Lake Superior and the Albany River [see p. 111-112]. Geological Survey of Canada, Report of Progress for *1871-72*, p. 101-114 (1872).

——— 1873. Report on the country between Lake Superior and Lake Winnipeg [see Surface geology note on p. 111]. Geological Survey of Canada, Report of Progress for *1872-73*, p. 87-111 (1873).

——— 1874. Report on the country between Red River and the South Saskatchewan, with notes on the geology of the region between Lake Superior and Red River [see Drift, p. 85-87]. Geological Survey of Canada, Report of Progress for *1873-74*, p. 66-90 (1874).

——— 1875. Report on the country west of lakes Manitoba and Winnipegosis with notes on the geology of Lake Winnipeg [see Superficial geology of the Northwest Territory, p. 40-53]. Geological Survey of Canada, Reports of Exploration and Surveys, *1874-75*, p. 24-56 (1876).

——— 1877. Report on an exploration in 1865 [1875] between James Bay and lakes Superior and Huron [see p. 325, 338-340]. Geological Survey of Canada, Reports on Exploration and Surveys *1875-76*, p. 294-342 (1877).

——— 1879a. Report on an exploration of the east coast of Hudson's Bay in 1877 [see Superficial geology, p. 29C-32C]. Geological Survey of Canada, Reports of Exploration and Surveys, *1877-78*, p. 1-37C (1879).

——— 1879b. Report on the country between Lake Winnipeg and Hudson's Bay, 1878 [see Surface geology, p. 24CC-28CC]. Geological Survey of Canada, Reports of Exploration and Surveys, *1877-78*, p. 1CC-31CC (1879).

——— 1880. Report on explorations on the Churchill and Nelson rivers and around God's and Island lakes, 1879 [see Glacial striae, p. 38C-41C]. Geological Survey of Canada, Report of Explorations and Surveys *1878-79*, p. 1C-44C (1880).

——— 1884. Report on part of the basin of the Athabasca River, Northwest Territory, 1882-83 [see Surficial geology, p. 28CC-30CC]. Geological and Natural History Survey of Canada, 1882-83-84, p. 1-35CC (1885).

——— 1886. Report on exploration of portions of the Attawapishkat and Albany rivers, Lonely Lake to James Bay [see Composition of the drift, p. 21G; Striae and drift deposits, p. 34-38G]. Geological and Natural History Survey of Canada, Annual Report, Vol. II, *1886* (1887).

Blake, W. Jr., 1966. End moraines and deglaciation chronology in northern Canada with special reference to southern Baffin Island. Geological Survey of Canada, Paper 66-26, 31 p.

——— 1970. Studies of glacial history in Arctic Canada. I. Pumice, radiocarbon dates and differential post-glacial uplift in the eastern Queen Elizabeth Islands. Canadian Journal of Earth Sciences, 7: 634-664.

Carozzi, A. V., 1984. Glaciology and the Ice Age. Journal of Geological Education, 32: 158-170.

Chalmers, R. 1883. On the surface geology of the Baie des Chaleurs region. Canadian Naturalist, 10(4): 193-212.

——— 1885. Preliminary report on the surface geology of New Brunswick. Part GG, 51 p. Geological and Natural History Survey of Canada, Annual Report, Vol. 1, *1885* (1886).

——— 1887. Surface geology, northern New Brunswick and south-eastern Quebec. Part M, 39 p. Geological and Natural History Survey of Canada, Annual Report, Vol. II, *1886* (1887).

——— 1888. Report on the surface geology of North-eastern New Brunswick. Part N, 33 p. Geological and Natural History Survey of Canada, Annual Report, Vol. III, Part 2, *1887-88* (1889).

——— 1890. Report on the surface geology of southern New Brunswick. Part N, 92 p. Geological and Natural History Survey of Canada, Annual report, Vol. IV, Part 2, *1888-89*, (1890) [see Striae, p. 36-47N and Conclusions regarding glacial phenomena, p. 47-52 N].

——— 1895. Report on the surface Geology of eastern New Brunswick, north-eastern Nova Scotia, and a portion of Prince Edward Island, Part M. 149 p. Geological Survey of Canada, Annual report, Vol. VII, *1894* (1896) [see mainly Glacial period and Striae, p. 50-83M and Glaciation of Nova Scotia, p. 95-97M].

——— 1906. Surface geology of eastern Québec. Geological Survey of Canada, Annual Report *1904*, Vol. 15, Part A: 250-263.

Chamberlin, T. C., 1894. Ideal map of North America during the Ice Age, Pl. XIV, Chapter 41, Glacial phenomena of North America, p. 724-775. *In* J. Geikie, ed., The Great Ice Age, 3rd Edition, Edward Stanford, London, 850 p. (1895).

——— 1907. The Pleistocene or glacial period, Fig. 469 and 470, Chapter *IX*. *In* T. C. Chamberlin and R. D. Salisbury, ed., vol. III, Earth History, 2nd Edition. American Science Series, Advanced course, Henry Holt, 624 p.

——— 1913. Map of North America during the Great Ice Age, Rand McNally, Chicago (scale: 1 inch to 104 miles or 169 km).

Coleman, A. P. 1926. Ice ages recent and ancient, MacMillan, New York, 296 p.

Coleman, A. P. and Parks, W. A., 1922a. 'Elementary geology' with special reference to Canada. I. M. Dent & Sons, Toronto [see Fig. 188, Glacial Map of North America].

——— 1922b. Physiography and glacial geology of Gaspé Peninsula, Québec. Geological Survey of Canada Museum Bulletin 34, 52 p.

Conrad, T., 1839. Notes on American Geology. American Journal of Science, 35: 237-251.

Craig, B. G. and Fyles, J. D., 1960. Pleistocene geology of Arctic Canada, Geological Survey of Canada, Paper 60-10, 21 p.

David, P. P. and Lebuis, J., 1985. The last glacial maximum and deglaciation of the western half of Gaspé Peninsula and adjacent area, Québec, Canada. Geological Society of America, Special Paper 197, p. 85-109.

Dawson, J. W., 1872. The post-Pliocene geology of Canada. The Canadian Naturalist, New Series VI(1): 19-42 [map opposite p. 19].

Dawson, G. M., 1887. Notes to accompany a geological map of the northern portion of the Dominion of Canada, east of the Rocky Mountains [see p. 56-58R]. Geological and Natural History Survey of Canada. Annual Report *1886*, Part R, 62 p.

——— 1891. On the later physiographical geology of the Rocky Mountain region in Canada, with special reference to changes in elevation and to the history of the glacial period [see Glacial history, p. 25-74]. Transactions of the Royal Society of Canada for the year 1890, Vol. VIII, Sect. IV.

Demorest, M., 1943. Ice sheets. Geological Society of America Bulletin, 54: 363-400.

Denton, G. H. and Hughes, T. J., 1981. The last great ice sheets. John Wiley and Sons, New York, 484 p.

Dredge, L. A. and Grant, D. R., 1987. Glacial deformation of bedrock and sediment, Magdalen Islands and Nova Scotia, Canada: Evidence for a regional grounded ice sheet, p. 183-195. *In* J. J. M. Van der Meer, ed., Tills and glaciotectonics. A. A. Balkema, Rotterdam.

Dyke, A. S., Dredge, L. A. and Vincent, J.-S., 1982. Configuration and dynamics of the Laurentide Ice Sheet during the Late Wisconsinan maximum. *Géographie physique et Quaternaire, 36: 5-14.*

Dyke, A. S. and Prest, V. K., 1987. Late Wisconsinan and Holocene history of the Laurentide Ice Sheet. Géographie physique et Quaternaire, 41: 237-263.

Dyke, A. S., Morris, T. F. and Green, D. E. C., 1989. Postglacial tectonic and sea level history of the central Canadian Arctic. Geological Survey of Canada, Bull. 897 (in press).

Ells, R. W., 1888. Geology of a portion of the Province of Quebec. Geological and Natural History Survey of Canada, Annual Report, Vol. 111, Pt. 2, *1887-88 (1889)*, Report K [see p. 98K-100K].

England, J., 1976. Late Quaternary glaciation of the eastern Queen Elizabeth Islands, Northwest Territories, Canada: Alternative models. Quaternary Research, 6(1): 185-202.

Fisher, D. A., Rhee, N. and Langley, K., 1985. Objective reconstructions of the Late Wisconsinan Laurentide Ice Sheet and the significance of deformable beds. Géographie physique et Quaternaire, 39: 229-238.

Flint, R. F., 1943. Growth of the North American ice sheet during the Wisconsin age. Geological Society of America, Bulletin, 54: 325-362.

——— 1947. Glacial geology and the Pleistocene Epoch. John Wiley & Sons, New York.

——— *1957. Glacial and Pleistocene geology. John Wiley & Sons,* New York, 553 p.

——— 1971. Glacial and Quaternary geology. John Wiley & Sons, New York, 872 p. [see Fig. 18-5, p. 478].

Fortier, Y. O. and Morley, L. M., 1956. Geological unity of the Arctic Islands. Transactions Royal Society of Canada, 50, Series 3, p. 3-12.

Fulton, R. J. and Prest, V. K., 1987. Introduction: The Laurentide Ice Sheet and its significance. Géographie physique et Quaternaire, 41: 181-186.

Fyles, J. G., 1965. Surficial geology, Western Queen Elizabeth Islands. *In* Report of Activities; Field, 1964. Geological Survey of Canada, Paper 65-1, p. 3-5.

Glacial Map of North America, 1945. Geological Society of America, Washington; 2 sheets, scale 1:4,555,000. 2nd Edition 1949.

Goldthwait, J. W., 1924. Physiography of Nova Scotia. Geological Survey of Canada, Memoir 140, 179 p.

Hattersley-Smith, G., 1969. Glacial features of Tanquary Fiord and adjoining areas of northern Ellesmere Island, N.W.T. Journal of Glaciology, 8(52): 23-50.

Hitchcock, E., 1841. First Anniversary Address before the Association of American Geologists. American Journal of Science, 41: 232-275.

Hitchcock, C. H., 1878. Glacial drift, p. 177-340. *In* W. Upham and C.H. Hitchcock, ed., The Geology of New Hampshire, Part III, Surface Geology. Concord, 386 p. [includes Map of eastern North America].

Hodgson, D. A., 1990. Were erratics moved by glaciers or icebergs to Prince Patrick Island, western Arctic Archipelago, Northwest Territories? *In* Current Research, Part F. Geological Survey of Canada, Paper 90-1F (in press).

Hoffman, P. F., 1968. Stratigraphy of the lower Proterozoic (Aphebian) Great Slave Supergroup, East arm Great Slave Lake, District of Mackenzie. Geological Survey of Canada, Paper 68-42, 93 p.

Hughes, T., Denton, G. H., and Grosswald, M. G., 1977. Was there a Late Würm Arctic ice sheet? Nature, 266: 596-602.

Ives, J. D., 1957. Glaciation of the Torngat Mountains, northern Labrador. Arctic, 10: 67-87.

——— 1978. The maximum extent of the Laurentide Ice Sheet along the east coast of North America. Arctic, 31: 24-53.

Ives, J. D. and Andrews, J. T., 1963. Studies in the physical geography of north-central Baffin Island, NWT. Geographical Bulletin, 19: 5-48.

Ives, J. D., Andrews, J. T. and Barry, R. G., 1975. Growth and decay of the Laurentide Ice Sheet and comparison with Fenno-Scandinavia. Die Naturwissenschaften, 62: 118-125. (see Fig. 1,4).

Jackson, G. D., 1960. Belcher Islands, Northwest Territories. Geological Survey of Canada, Paper 60-20, 13 p., Map 28, 1960.

Keyes, C., 1935a. Strategic role of Patrician glaciation in cosmic scheme. Pan-American Geologist, 63: 26-30 [see Pl. iii].

——— 1935b. Last epochal glaciations in cosmical paradigm. Pan-American Geologist, 63: 119-150 [see p. xii, xiii, xiv].

Kaszycki, C. A. and DiLabio, R. N. W., 1986. Surficial geology and till geochemistry, Lynn Lake-Leaf Rapids region, Manitoba,

p. 245-266. *In* Current Research, Part B, Geological Survey of Canada, Paper 86-1B.

Kite, J. S., Lowell, T. V. and Thompson, W. B., eds., 1986. Contributions to the Quaternary geology of northern Maine and adjacent Canada. Maine Geological Survey, Bulletin 37, 141 p.

Lagerlund, E., 1987. An alternative Weichselian glaciation model, with special reference to the glacial history of Skåne, South Sweden. Boreas, 16: 433-459.

Lee, H. A., 1959. Surficial geology of southern Keewatin and the Keewatin Ice Divide, Northwest Territories. Geological Survey of Canada, Bulletin 51, 42 p.

Lee, H. A., Craig, B. G., and Fyles, J. G., 1957. Keewatin Ice Divide. Bulletin Geological Society of America, 68: 1760-61 (abstract).

Legget, R. F., ed., 1961. Soils in Canada, Geological, Pedalogical, and Engineering Studies. Royal Society of Canada, Special Publications, No. 3, University of Toronto Press, 239 p.

Logan, W. E., 1847. Lake Temiscamang valley, glacial action [see Glacial action, p. 72-75]. Geological Survey of Canada, Report of Progress for the year *1845-46*.

——— 1863. Superficial geology [see Map VI]. Geological Survey of Canada Report of Progress *1842-1863*, p. 886-930.

Low, A. P., 1888. Report on explorations in James' Bay and country east of Hudson Bay [see Islands, p. 24-37J, and Glaciation and superficial deposits, p. 61-62J]. Geological and Natural History Survey of Canada, Report J, Annual Report, Vol. III, Part II, *1887-88* (1889).

——— 1889. On the geology and economic minerals of the southern portion of Portneuf, Quebec and Montmorency Counties, Quebec [Lake St. John region; see Surficial deposits, p. 47-66L]. Geological Survey of Canada, Report L, Annual Report, Vol. V, Part I, *1890-91* (1893).

——— 1896. Report on explorations in the Labrador Peninsula along the Eastmain, Koksoak, Hamilton, Maniquagan and portions of other rivers 1892-95 [see Glacial geology, p. 289-311L]. Geological Survey of Canada, Annual Report L, Annual Report, Vol. VIII, *1895* (1897).

——— 1902. Report on the exploration of the eastcoast of Hudson Bay [see p. 81D]. Geological Survey of Canada, Report D, Annual Report, Vol. III, *1900* (1903).

——— 1903. Report on the geology and physical character of Nastapoka Islands, Hudson Bay [see, p. 24-25DD]. Geological Survey of Canada, Report DD, Annual Report, Vol. XIII, *1900* (1903).

Mackay, J. R., 1965. Glacier flow and analogue simulation. Geographical Bulletin, 7: 1-6.

MacLean, A., 1944. Pleistocene glaciation: area adjacent to St. Lawrence Valley. *In* J. A. Dresser and T. C. Denis, ed., Descriptive geology. Geological Report 20, Québec Department of Mines.

Marlowe, J. L., 1968. Sedimentology of the Prince Gustav Adolph Sea area, District of Franklin, Geological Survey of Canada, Paper 66-29: 1-23.

Martin, L., 1924. Figure 172. *In* R. S. Tarr and L. Martin, ed., College Physiography. MacMillan, New York, 837 p.

——— 1916. The physical geography of Wisconsin. Wisconsin Geological and Natural History Survey, Bulletin 36, Educational Series No. 4, 549 p. [see Fig. 27].

——— 1932. The physical geography of Wisconsin, 2nd Edition. Wisconsin Geological and Natural History Survey, Bulletin 36, 608 p.

——— 1935. Patrician Ice Sheet on North American glacial maps. Pan-American Geologist, 65 (4): 8-11 [see Pl. ii].

Mayewski, P. A., Denton, G. H. and Hughes, T. J., 1981. Figures 2-4 and 2-5, Chapter, 2, p. 67-178. *In* G. H. Denton and T. J. Hughes, ed., The last great ice sheets, John Wiley and Sons, New York, 484 p.

McConnell, R. G., 1891. Report on an exploration in the Yukon and Mackenzie basins, N.W.T. Geological and Natural History Survey of Canada, Annual Report, Vol. IV, *1888-89* (1890), Report D [see Superficial deposits and glacial action, p. 24-28D].

——— 1893. Report on a portion of the District of Athabasca comprising the country between Peace River and Athabasca River, north of Lesser Slave Lake. Geological Survey of Canada, Annual Report, Vol. V, Part I, *1890-91* (1893), Report D [see Glacial Geology, p. 59-62D].

McEwen, J. H., 1978. Calcareous concretions of the Omarolluk Formation, Belcher Islands, Northwest Territories. B. Sc. Honours Thesis, Department of Geology, Carleton University, Ottawa.

McGerrigle, H. W., 1952. Pleistocene glaciation of Gaspé Peninsula. History: Development of various theories. Transactions of the Royal Society of Canada, 46, series 3, section 4: 37-51.

Morey, G. B. and Ojakangas, R. W., 1970. Sedimentology of the Middle Precambrian Thomson Formation, East-central Minnesota. Minnesota Geological Survey, Report of Investigations 13.

Muller, D. S., 1980. Glacial geology and Quaternary history of southeast Meta Incognita Peninsula, Baffin Island, Canada. M.Sc. thesis, University of Colorado, 211 p.

Occhietti, S., 1987. Dynamique de l'Inlandsis laurentidien du Sangamonien à la Holocène. Géographie physique et Quaternaire, 41 (2): 301-323.

Pelletier, B. R., 1962. Submarine geology programme, Polar Continental Shelf Project, Isachsen, District of Franklin. Geological Survey of Canada, Paper 61-21: 1-10.

Pirsson, L. V. and Schuchert, C., 1924. A textbook of geology, Part II (Schuchert) 1924, Fig. 227, p. 651 (after Martin, 1916). John Wiley & Sons, New York.

Prest, V. K. 1957. Pleistocene geology and surficial deposits, Chapter VIII [see Fig. 81]. *In* C. H. Stockwell, ed., Geology and Economic Minerals of Canada, 4th edition. Economic Geology Series No. 1, Geological Survey of Canada.

——— 1961. Geology of the soils of Canada, p. 6-21 *In* R. F. Legget, ed., Soils in Canada: geological, pedological and engineering studies. Royal Society of Canada, Special Publication No. 3.

——— 1963. Red-Lake-Lansdowne House area, Northwestern Ontario: Surficial geology. Geological Survey of Canada, Paper 63-6, 23 p.

——— 1967. Stages in the deglaciation of Wisconsin ice, Fig. XII-15. *In* Quarternary geology of Canada, Chapter XII, p. 676-764, Geology and Economic Minerals of Canada, 5th edition. Economic Geology Report No. 1, Geological Survey of Canada, 1970.

——— 1969. Retreat of Wisconsin and Recent ice in North America. Geological Survey of Canada, Map 1257A, scale: 1:5,000,000.

——— 1970. Quarternary geology of Canada, Chapter XII. *In* Geology and Economic Minerals of Canada, 5th edition. Economic Geology Report, Geological Survey of Canada.

——— 1973. Surficial deposits of Prince Edward Island. Geological Survey of Canada, Map 1366A.

——— 1983. Canada's heritage of glacial features/L'héritage glaciaire du Canada, Geological Survey of Canada, Miscellaneous Report 28, 120 p. [see Fig. 1, The Late Wisconsinan glacier complex/Le complexe glaciaire du Wisconsinien supérieur].

——— 1984. The Late Wisconsinan glacier complex. p. 21-36 [see p. 22-23 and Map 1584A]. *In* R. J. Fulton, ed., Quaternary stratigraphy of Canada — A Canadian contribution to IGCP project 24. Geological Survey of Canada, Paper 84-10.

Prest, V. K., Terasmae, J., Matthews, J. V., Jr. and Lichti-Federovich, S., 1976. Late Quaternary history of Magdalen Islands, Québec. Maritime Sediments, 12: 39-59.

Prest, V. K. and Nielsen, E., 1987. The Laurentide Ice Sheet and long-distance transport. Geological Survey of Finland, Special Paper 3: 91-101 [see p. 96-99 and Fig. 2].

Rampton, V. N., Gauthier, R. C., Thibault, J. and Seaman, A. A., 1984. Quaternary geology of New Brunswick. Geological Survey of Canada, Memoir 416, 77 p.

Reeh, N., 1982. A plasticity theory approach to the steady-state shape of a three-dimensional ice sheet. Journal of Glaciology, 28 (100): 431-455.

Ricketts, B. D., 1981. A submarine fan-distal molasse sequence of Middle Precambrian age, Belcher Islands, Hudson Bay. Bulletin of Canadian Petroleum Geology, 29: 561-582.

Shaler, N. S. and Davis, W. M., 1881. Illustrations of the Earth's Surface-Glaciers [see Plate XXV]. Osgood and Company, Boston.

Shilts, W. W., 1980. Flow patterns in the central North American ice sheet. Nature, 286: 213-218.

——— 1982. Quaternary evolution of the Hudson/James Bay region. Le Naturaliste canadien, 109: 309-332.

——— 1985. Geological models for the configuration, history and style of deglaciation of the Laurentide Ice Sheet, p. 73-91. *In* M. J. Wodenberg, ed., Models in geomorphology. The Binghamton Symposia in geomorphology, International Series, Vol. 14, Allen and Unwin, London.

Shilts, W. W., Cunningham, C. M. and Kaszycki, C. A., 1979. Keewatin Ice Sheet — Re-evaluation of the traditional concept of the Laurentide Ice Sheet. Geology, 7: 537-541.

Shilts, W. W. and Aylsworth, J. M., 1987. Glacial geomorphology of northwestern Canadian Shield, p. 126-150. *In* W. L. Graf, éd., Geomorphic Systems of North America. Geological Society of America, Centennial Special Volume 2.

Sim, W. V., 1960. A preliminary account of Late Wisconsin glaciation in Melville Peninsula, N.W.T. Canadian Geographer, 17: 21-33.

Stockwell, C. S., 1933. Great Slave Lake-Coppermine River area, Northwest Territories. Geological Survey of Canada, Summary Report 1932, Part C: 37-63.

——— 1936. Eastern portion of Great Slave Lake (west half), District of Mackenzie, Northwest Territories (Map 377A). Geological Survey of Canada.

——— 1968. Christie Bay, Great Slave Lake, Northwest Territories (Map 1122A). Geological Survey of Canada.

Tarr, R. S. and Martin, L., 1914. College Physiography. MacMillan, New York.

Tozer, E. T., 1956. Geological reconnaissance, Prince Patrick, Eglinton, and western Melville islands, Arctic Archipelago, Northwest Territories. Geological Survey of Canada, Paper 55-5.

Tozer, E. T. and Thorsteinsson, R., 1964. Western Queen Elizabeth Islands, Arctic Archipelago. Geological Survey of Canada, Memoir 332, 242 p.

Tyrrell, J. B., 1888. Notes to accompany a preliminary map of the Duck and Riding Mountains in northwestern Manitoba, Geological and Natural History Survey of Canada, Report E. Vol. III, Pt. I,*1887-88*, 16 p. (1889).

——— 1887-90 (1892). Northwestern Manitoba with portions of the districts of Assiniboia and Saskatchewan [see p. 216a]. Geological Survey of Canada, Report of Progress *1890-81*, Pt. I (1893), 235 p.

——— 1892. Report on North-western Manitoba with portions of the adjacent districts of Assiniboia and Saskatchewan. Geological Survey of Canada, Annual Report, Vol. V, Pt. I, *1890-91* (1893), Report E [see Pleistocene, p. 215-218E].

——— 1896. Report on the country between Athabaska Lake and Churchill River. Geological Survey of Canada, Annual Report, Vol. VIII, *1895* (1897) [see Pleistocene, p. 20D].

——— 1896. Report on the Doobaunt, Kazan and Ferguson rivers and the Northwest coast of Hudson Bay. Geological Survey of Canada, Annual Report, Vol. IX, *1896* (1898) Report F. Diagram 621 [see Pleistocene, p. 175-193F].

——— 1898. The glaciation of north-central Canada. Journal of Geology, 6(2): 147-160 [see Pl. V and VI].

——— 1913b. Hudson Bay Exploring Expedition 1912. Ontario Bureau of Mines, Annual Report, Vol. XXII, Pt. I [see Pleistocene, p. 196-209, reprint, p. 1-51, Pleistocene, p. 38-51].

——— 1913a. The Patrician glacier south of Hudson Bay. Congrès géologique international, 12e session, Canada, p. 523-534.

——— 1935. Discovery of Patrician center of ice dispersion, p. 1-15. *In* Patrician center of glaciation: A Symposium. Pan-American Geologist, 63: 1-30.

Upham, W., 1895. Map showing the relationship of Lake Agassiz to the drift-bearing area of North America and to Lakes Bonneville and Lahontan. *In* The Glacial Lake Agassiz. United States Geological Survey, Monograph XXV, Pl. 2 (1896).

Veillette, J. J., 1988. Observations sur la géologie glaciaire du nord-est de la Gaspésie, Québec, p. 209. *In* Recherche en cours, partie B, Commission géologique du Canada, Étude 881B.

Vincent, J.-S., 1982. The Quaternary history of Banks Island, Northwest Territories, Canada. Géographie physique et Quaternaire, 36: 209-232.

Vincent, J.-S. and Prest, V. K., 1987. The Early Wisconsinan glacial history of the Laurentide Ice Sheet. Géographie physique et Quaternaire, 41: 199-213.

Wickenden, R. T. D., 1947. Pleistocene Glacial Deposits, Geology and Economic Minerals of Canada, Economic Geology Series, No. 1, 3rd edition., p. 325-346.

Wilson, J. T., Falconer, G., Mathews, W. H. and Prest, V. K., 1958. Glacial Map of Canada. Geological Association of Canada.